*American*

# POTATO JOURNAL

*Volume 35* *September 1958* *Number 9*

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*Official Publication of*

**THE POTATO ASSOCIATION OF AMERICA**

**NEW BRUNSWICK, NEW JERSEY, U. S. A**

# American Potato Journal

PUBLISHED BY
THE POTATO ASSOCIATION OF AMERICA
NEW BRUNSWICK, N. J.

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Entered as second class matter at New Brunswisk, N. J., March 14, 1942 under Act of March 3, 1879. Accepted for mailing at special rate of postage provided for in section 412, Act of February 28, 1925, authorized on March 14, 1928.

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# NITROGEN FERTILIZATION OF POTATOES[1]

R. L. Sawyer and S. L. Dallyn[2]

Nitrogen is available for potato fertilization in many forms with considerable variation in price. The work reported here was aimed at finding out the best source of nitrogen and method of application in order to furnish the required nitrogen in the most economical manner.

Principal response in potato fertilization on Long Island has been from nitrogen as shown by Jacob, White-Stevens and Wessels (2). Ellison and Jacob (1) found that Cobbler and Katahdin varieties required 140 pounds of nitrogen per acre and mentioned unpublished data which indicated a benefit from nitrogen sidedressing of 30 to 60 pounds, especially when heavy spring rains leached the nitrogen applied at planting time. Lorenz and Johnson (3) found that for a number of California soils, ammonium fertilizers provide greatly increased yields compared with nitrate fertilizers.

## Materials and Methods

In 1954 two varieties of potatoes, Katahdin and Cobbler were given the following split plot and factorial treatments.

A. Varieties (Main Split)
   1 Katahdin
   2 Cobbler

B. Time of Sidedressing (2nd Split)
   1 Early (2 to 4 inch plant stage)
   2 Late (10 to 12 inch plant stage)

C. Planting Nitrogen - Lbs./A.
   1 70
   2 140

D. Type of Nitrogen Sidedressing
   1 Liquid (Solution 2A)
   2 Dry (Aeroprills)

E. Sidedressing Nitrogen - Lbs./A
   1 0
   2 35
   3 70

$P_2O_5$ and $K_2O$ were applied at the rate of 140 pounds per acre and MgO at 50 pounds per acre. Potatoes were planted March 31 and harvested September 25 and 26. The plots were four rows wide and 25 feet long. The treatments were similar in 1955 except that the late sidedressing was applied when plants were in the 6″ to 8″ stage of development. The planting date was March 31st and the harvest dates were September 8 and 12.

In a second nitrogen experiment started in 1955 the treatments were similar for both 1955 and 1956. Cobbler and Katahdin potatoes received the following factorial treatments.

[1]Accepted for publication January 17, 1958.
Paper No. 413, Department of Vegetable Crops, Cornell University, Ithaca, N. Y.
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| A. Nitrogen Fertilization Treatments Lbs./A | | B. Time of sidedress |
|---|---|---|
| Planting Nitrogen | Sidedress Nitrogen | 1. Comeup |
| 1 0 | 175 | 2. 4 to 6 inch plant stage. |
| 2 35 | 140 | |
| 3 70 | 105 | |
| 4 105 | 70 | |
| 5 140 | 35 | |
| 6 175 | 0 | |

All plots were 4 rows wide and 33 feet long, and were fertilized with $P_2O_5$ and $K_2O$ at 140 pounds per acre, and MgO at 50 pounds per acre. Sidedress nitrogen was in the form of Solution 2, 18.26 per cent ammonia, and 22.75 ammonium nitrate. Planting nitrogen was in the form of ammonium nitrate.

In 1955, all potatoes were planted on March 30 and were harvested September 13. In 1956 they were planted April 11 and the Cobbler variety harvested September 12, and the Katahdins on September 21. The come-up sidedressing was applied when rows could first clearly be delineated from the emerging plants.

In 1956 the treatments for the previously described experiment were changed to include increments of 35 pounds per acre up to a total of 210. The treatments were as follows.

| | Planting Nitrogen | Sidedress Nitrogen | | Planting Nitrogen | Sidedress Nitrogen |
|---|---|---|---|---|---|
| 1 | 0 | 210 | 8 | 0 | 175 |
| 2 | 35 | 175 | 9 | 35 | 140 |
| 3 | 70 | 140 | 10 | 70 | 105 |
| 4 | 105 | 105 | 11 | 105 | 70 |
| 5 | 140 | 70 | 12 | 140 | 35 |
| 6 | 175 | 35 | 13 | 175 | 0 |
| 7 | 210 | 0 | 14 | 140 | 0 |

Both Katahdin and Cobbler varieties were planted on April 8. The Cobblers were harvested on September 5 and the Katahdin on September 13.

In 1956 and 1957 comparisons were made of several methods by which potatoes could receive supplemental nitrogen with treatments as follows.

| A. Nitrogen Division - Lbs./A. | | B. Sidedressing Materials and Time |
|---|---|---|
| Planting | Sidedressing | 1 Cyanamid before plowing |
| 1 170 | 0 | 2 Anhydrous after planting |
| 2 140 | 35 | 3 Solution 2 at 4 to 6-inch plant stage |
| 3 105 | 70 | |

Planting nitrogen was in the form of ammonium nitrate. $P_2O_5$ and $K_2O$ were applied at the rate of 140 pounds per acre and MgO at 50 pounds per acre. The plots were 4 rows wide and 25 feet long with 4 replications in a factorial of randomized block design. The tubers of the Katahdin variety were planted April 12 and harvested September 21 in 1955. In 1956 Katahdin tubers were planted April 10 and harvested September 20.

All the work covered in these experiments was under the irrigated conditions common to Long Island. In these experiments, tubers were allowed to grow to full maturity. Only the two center rows of the four-row plots were used for yield and sampling data. No sprayer wheel rows were included in any of the plots. Foliage readings were made in early June and again in August to determine how treatments had affected maturity. Samples from each variety were saved at harvest time and stored at 50° F. for storage determinations on black spot, chipping color, sprouting and shrinkage. (Storage determinations were made 5 to 6 months from harvest).

## Results and Discussion

In the experiments comparing various levels of nitrogen, the yield of Katahdin leveled off at 175 pounds of nitrogen per acre in 1954, and in 1955 the yield continued to increase to the highest dosage level which was 210 pounds per acre. The yield of Cobbler continued to increase from the lowest to the highest dosage level. These results are given in table 1. The only level in this experiment where the value of sidedressing could be determined was at 140 pounds per acre. Seventy pounds at planting plus 70 pounds at sidedressing gave a response similar to 140 pounds applied at planting. Similar yield responses were obtained with the early and late sidedressing. In general, there was a trend for the high nitrogen levels to give lower specific gravity tubers than did the low nitrogen levels, although the differences were small.

In the set of experiments comparing all nitrogen at planting with all nitrogen at sidedressing and all the possible combinations in between at 35-pound increments, less than 70 pounds at planting gave delayed maturity. The "come up" supplement tended to give earlier maturity than the 4 to 6-inch supplement. Varying the nitrogen from all at planting to all at sidedressing had no effect on yield of Katahdins when the vines were allowed to go to maturity. With the Cobbler variety in 1956 there were no differences in yield caused by the various treatments. However, in 1957 the "come up" supplemental application gave a better yield than the 4 to 6-inch application. With Cobbler there was no consistent trend as increments were increased from all at planting to all at sidedressing, however, putting all nitrogen on at sidedressing gave the lowest yields. With both varieties, applying the supplemental nitrogen at "come up" gave higher specific gravity tubers than did the 4 to 6-inch supplement. The results of the experiment with Katahdins are given in table 2, and the test with Cobblers is recorded in table 3.

In the comparison of various types of supplemental nitrogen similar results were obtained with the liquid Solution 2 and the dry Aeroprills

TABLE 1.—*Effect of nitrogen fertilization on yield of potatoes for 1954-1955.*

| Nitrogen Distribution Lbs./A. | | | U.S. No. 1 Bu./A. | | | | |
|---|---|---|---|---|---|---|---|
| | | | Cobbler 1954 — 1955 | | Katahdin 1954 — 1955 | | Specific Gravity Katahdin 1955 |
| Planting | Sidedress | Total | | | | | |
| 70 | 0 | 70 | 379 | 377 | 480 | 483 | 1.0675 |
| 70 | 35 | 105 | 440 | 442 | 566 | 534 | 1.0674 |
| 70 | 70 | 140 | 474 | 477 | 602 | 574 | 1.0656 |
| 140 | 0 | 140 | 494 | 495 | 614 | 603 | 1.0655 |
| 140 | 35 | 175 | 518 | 540 | 659 | 621 | 1.0660 |
| 140 | 70 | 210 | 537 | 576 | 653 | 659 | 1.0642 |
| L.S.D. | | | 69 | 48 | 69 | 48 | .0033 |
| Type of Sidedressing | | | | | | | |
| Liquid | | | 488 | 498 | 637 | 583 | 1.0664 |
| Dry | | | 497 | 518 | 603 | 584 | 1.0652 |
| | | | ns | ns | ns | ns | ns |
| Date of Sidedressing | | | | | | | |
| 2"—4" | | | 493 | 522 | 613 | 592 | 1.0660 |
| 8"—12" | | | 479 | 495 | 609 | 576 | 1.0656 |
| | | | ns | ns | ns | ns | ns |

TABLE 2.—*Effect of nitrogen distribution on yield, maturity and specific gravity of Katahdin tubers.*

| Nitrogen Distribution | | | Bus./A. Yield—U.S. No. 1 | | | Maturity Rating | | | Specific Gravity | |
|---|---|---|---|---|---|---|---|---|---|---|
| Planting | Sidedress | Total | 1955 | 1956 | 1957 | 1955 | 1956 | 1957 | 1955 | 1956 |
| 0 | 175 | 175 | 589 | 603 | 758 | 3.9 | 6.8 | 8.1 | 1.0666 | 1.0763 |
| 35 | 140 | 175 | 566 | 574 | 771 | 6.6 | 7.6 | 7.7 | 1.0690 | 1.0754 |
| 70 | 105 | 175 | 602 | 574 | 735 | 7.1 | 8.0 | 8.2 | 1.0670 | 1.0763 |
| 105 | 70 | 175 | 592 | 591 | 770 | 8.6 | 9.0 | 8.3 | 1.0685 | 1.0773 |
| 140 | 35 | 175 | 528 | 575 | 747 | 8.9 | 8.6 | 8.3 | 1.0697 | 1.0779 |
| 175 | 0 | 175 | 589 | 572 | 740 | 8.8 | 8.4 | 8.0 | 1.0676 | 1.0748 |
| Time of Sidedressing | | | | | | | | | | |
| Come up | | | 575 | 579 | 763 | 7.4 | 8.6 | 7.9 | 1.0686 | 1.0773 |
| 4" — 6" | | | 580 | 582 | 747 | 7.2 | 7.5 | 7.0 | 1.0675 | 1.0753 |
| Source | | D.F. | Mean Squares | | | | | | | |
| Replications | | 3 | 31 | 86 | 168 | .3 | 5.0 | .3 | 22.3 | 32.3 |
| Nitrogen Distribution | | 5 | 105 | 10 | 292 | 29.8 | 13.0 | 1.1 | 12.8 | 10.6 |
| Application Time | | 1 | 14 | 130 | 362 | 1.0 | 3.0 | 1.0 | 14.0 | 44.0 |
| Error | | 33 | 246 | 85 | 273 | .4 | .8 | .7 | 5.9 | 12.3 |

TABLE 3.—*Effect of nitrogen distribution on yield, maturity and specific gravity of Cobbler tubers.*

| Nitrogen Distribution | | | Bus./A. Yield—U.S. No. 1 | | Maturity Rating | | Specific Gravity | |
|---|---|---|---|---|---|---|---|---|
| Planting | Sidedress | Total | 1956 | 1957 | 1956 | 1957 | 1956 | 1957 |
| 0 | 175 | 175 | 501 | 480 | 6.3 | 5.2 | 1.0743 | 1.0741 |
| 35 | 140 | 175 | 531 | 572 | 8.1 | 7.1 | 1.0745 | 1.0743 |
| 70 | 105 | 175 | 518 | 537 | 8.6 | 7.5 | 1.0738 | 1.0744 |
| 105 | 70 | 175 | 538 | 575 | 7.9 | 7.8 | 1.0735 | 1.0748 |
| 140 | 35 | 175 | 555 | 636 | 8.5 | 8.5 | 1.0759 | 1.0756 |
| 175 | 0 | 175 | 516 | 562 | 8.6 | 7.3 | 1.0748 | 1.0764 |
| Time of Sidedressing | | | | | | | | |
| Come up | | | 526 | 581 | 8.5 | 7.9 | 1.0751 | 1.0754 |
| 4" — 6" | | | 529 | 550 | 7.6 | 7.0 | 1.0738 | 1.0737 |
| Source | | D.F. | | | | | Mean Squares | |
| Total | | 47 | | | | | | |
| Replications | | 3 | 106 | 3158 | .. | 5.3 | 2.0 | 15.0 |
| Nitrogen Distribution | | 5 | 188 | 1008 | 6.6 | 5.8 | 5.8 | 9.4 |
| Application Time | | 1 | 18 | 1457 | 9.0 | 20.0 | 23.0 | 86.0 |
| Error | | 33 | 110 | 50 | 1.1 | 1.2 | 4.2 | 5.6 |

TABLE 4.—*Effect of type of nitrogen fertilization on yield in bushels per acre and quality of tubers.*

| Sidedressing Material | | | 1957 | | Specific Gravity | 1956 |
|---|---|---|---|---|---|---|
| | | | U.S. No. 1 | Size 2"-3½" | | U.S. No. 1 |
| Cyanamid | | | 771 | 506 | 1.0695 | 640 |
| Anhydrous Ammonia | | | 762 | 480 | 1.0692 | 632 |
| Solution 2 | | | 777 | 494 | 1.0705 | 644 |
| | | | ns | ns | ns | ns |
| Nitrogen Distribution | | | | | | |
| Planting | Sidedress | Total | | | | |
| 105 | 70 | 175 | 758 | 484 | 1.0705 | 644 |
| 140 | 35 | 175 | 759 | 482 | 1.0695 | 630 |
| | | | ns | ns | ns | ns |

(Table 1). Table 4 gives the results of a comparison of cyanamid, anhydrous ammonia and Solution 2. These three materials gave similar tuber yields and specific gravities.

In storage determinations, there was no effect from the various nitrogen treatments on black spot, sprouting and shrinkage. There was a tendency for tubers receiving all of the nitrogen at planting to chip lightest.

Taking into consideration the various aspects of nitrogen fertilization reported in these experiments, the amount of nitrogen necessary for

maximum yield varies from year to year and from experiment to experiment within a given year. Maximum yields were consistently obtained at levels greater than 140 pounds of nitrogen per acre. The time of sidedressing had little effect on yield, however, in general the earlier the nitrogen was applied the earlier was the maturity and the higher the specific gravity. This is of particular importance to potato production aimed at early marketing.

The principal reason given for sidedressing on Long Island is that spring rains have leached out a portion of the planting nitrogen. Therefore, the normal cultural practice is to apply approximately 50 pounds of nitrogen at the 4 to 6-inch plant stage in addition to the 140 pounds applied at planting. These experiments on nitrogen distribution indicate that the reason for this sidedressing nitrogen is not due to leaching rains, but that the plants need this extra nitrogen, whether it be applied at planting time or later at sidedressing, for maximum yields. On particularly light soils the leaching factor is undoubtedly important. Nitrogen distribution had little effect on yield as long as the vines were allowed to go to full maturity. There was delayed maturity for potatoes receiving less than 70 pounds of nitrogen at planting.

## Summary

1. Yield increases under irrigated Long Island conditions were obtained with applications up to 210 pounds of nitrogen per acre with Cobbler and Katahdin varieties.

2. Nitrogen distribution had little effect on yield as long as vines were allowed to go to maturity.

3. When less than 70 pounds of the total nitrogen was applied at planting, maturity was delayed.

4. In general, the earlier the nitrogen was applied the higher was the specific gravity.

5. The nitrogen sources gave similar responses in all determinations made.

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# STUDY OF THE PHENOLIC COMPOUNDS IN POTATO TUBERS DURING STORAGE[1]

C. C. CRAFT[2], H. W. SIEGELMAN[2] AND W. L. BUTLER[3]

Phenolic compounds of potato tubers are involved in the enzymatic discoloration of raw potatoes and presumably in the after-cooking darkening of steamed or boiled potatoes (4, 17). Previous investigations showed chlorogenic and caffeic acids and tyrosine to be the principal phenolic compounds in potato tissue (5, 7, 9, 10, 11). In addition, tannin was reported as a cell inclusion of periderm cells (2) and 3, 4-dihydroxyphenylalanine was considered present (6). A glucoside of quercetin was reported in diseased potato tubers (14).

Several workers studied the effect of storage on after-cooking discoloration (17), but little work has been done on the effect of storage temperature and duration on the phenolic content. Smith *et al* (15) reported that the contents of tyrosine and 3, 4-dihydroxyphenylalanine were not altered appreciably by storage at 104° F. and Clark *et al* (7) reported that the phenolic contents of two varieties of potatoes did not increase with maturity. The purpose of this study was to identify by their reaction with iron the phenolic compounds possibly involved in after-cooking discoloration and to compare the phenolic contents of potato tubers stored at 55°, 40° and 32°.

## MATERIALS AND METHODS

Late-crop Russet Rural and Kennebec potatoes were obtained from Maine and weighed lots of 10 uniform-size tubers of each variety were placed in storage in ventilated polyethylene bags at 55°, 40° and 32° F. for quantitative estimation of phenolic compounds. Under these conditions weight loss was negligible during 5 months of storage. Similar lots of Kennebec potatoes were placed in 55° for a subsequent study of holding for 8 days at 96°. One-hundred-pound lots of each variety were held at 32° for the subsequent extraction and identification of the phenolic compounds.

## QUALITATIVE IDENTIFICATION

In the Russet Rural potatoes the phenolic compounds reacting with ferric chloride were identified by a combination of one- and two-dimensional paper chromatography, paper electrophoresis, ultraviolet spectrophotometry and spectrophotofluorimetry. The phenolic compounds in the Kennebec variety were identified by one- and two-dimensional paper chromatography after extraction and purification by procedures similar to those described for the Russet Rural variety.

Twenty-three kg. of cortex tissue from Russet Rural tubers were extracted in 1-kg. lots by blending with an equal volume of ethanol containing 4 gm. of disodium ethylenediaminetetraacetic acid and 0.5 gm. of potassium metabisulphite. The filtrate from the combined extracts was

[1]Accepted for publication February 28, 1958.

[2,3]Physiologist and Biophysicist, respectively, Biological Sciences Branch, Agricultural Marketing Service, U. S. Department of Agriculture, Beltsville, Md.

concentrated *in vacuo* at 35° C. to 1 liter and extracted with petroleum ether in a liquid-liquid extractor for 24 hours. The petroleum ether phase was discarded and the water phase was extracted with ethyl acetate for 5 days. The ethyl acetate extract containing the phenolic compounds was evaporated *in vacuo* almost to dryness and taken up in 100 ml. of methanol for chromatography.

The components of the methanol extract were partially purified by large-scale paper chromatography. Some 20 sheets of Whatman No. 3 chromatographic paper (18 x 22 in.) were striped with 1 ml. of extract per sheet and developed with 5 per cent aqueous acetic acid. The prominent blue fluorescent bands were marked under ultraviolet light and the bands reacting with ferric chloride were cut from the sheets and eluted by soxhlet extraction with methanol. The eluate from each band was concentrated to a small volume at 35° C. *in vacuo* and further purified by repeating the striping procedure and developing with the respective solvent system that gave the best separation as determined by a small-scale preliminary trial. After separation the bands reacting with ferric chloride were eluted and chromatographed with authentic compounds in a series of solvent systems for a comparison of $R_F$ values.

Two-dimensional chromatograms were made on Whatman No. 3 paper (18 x 22 in.) using n-butanol-acetic acid-water (6:1:2) first, across the short dimension of the paper and 5 per cent aqueous acetic acid secondly, across the long dimension. The papers were examined with ultraviolet light and the fluorescent areas marked. The reaction of the fluorescent areas to ammonia vapor was noted and the o-dihydroxyphenolic compounds on the chromatograms were located by spraying individual sheets with 1 per cent aqueous ferric chloride, a mixture of equal parts of 5 N ammonium hydroxide and 0.1N silver nitrate, Arnow's reagent (1) and a mixture of equal parts of 1 per cent ferric chloride and 0.3 per cent aqueous potassium ferricyanide followed by washing with water.

Paper electrophoresis was performed in an apparatus similar to that described by Kunkel and Tiselius (12) using Whatman No. 3 paper. The applied electric field was about 10 v/cm. Ultraviolet absorption spectra were determined with the Perkin-Elmer spectrophotometer and the fluorescence spectra with the Aminco-Bowman spectrophotofluorimeter. Spectral shifts were obtained by adding aluminum chloride and sodium acetate.

The identity of chlorogenic acid was further confirmed by saponification in 1 N aqueous sodium hydroxide at 100° C. for 5 minutes under nitrogen. The solution was desalted by passage through a 1 x 3 cm. column of IR-120 resin (30-60 mesh). The column was washed with water and the washings were acidified with formic acid and extracted with ethyl acetate. The ethyl acetate phase and the aqueous acid phase were chromatographed for the identification of the components of chlorogenic acid.

## Quantitative Estimation

Phenolic compounds are not uniformly distributed within the tissue of the potato tuber. An o-dihydroxyphenolic compound with the properties of chlorogenic acid is concentrated in the periderm and underlying cortical tissue (9). For quantitative estimation of the phenolic compounds it was necessary to select uniform-size tubers to maintain an equivalent surface

to volume ratio. At each sampling date 8 tubers of the 10-tuber sample from each storage temperature were split longitudinally from bud to stem end and half of each tuber was weighed and blended individually for 5 minutes with a double volume of ethanol. The blended mixture was made to volume in a 500-ml. flask with ethanol. Suitable aliquots were removed from this mixture for the estimation of total phenolics with the Folin-Denis reagent (13) and the estimation of o-dihydroxyphenolic compounds by the determination of the optical density at 325 mμ with a Beckman spectrophotometer. The optical density of each solution was also determined at 280 mμ.

The o-dihydroxyphenolic content of each variety of potato upon arrival after harvest was estimated by the nitrite-molybdate method of Arnow (1), as well as by the methods previously mentioned, and chlorogenic acid was estimated by the method of Weiss (16), developed for coffee, in which the phenolic compounds were precipitated by basic lead acetate and the chlorogenic acid was estimated by difference in optical density before and after precipitation. The phenolic contents of the harvest samples were estimated also by procedures similar to those described by Kuc' *et al* (11) by which the phenolic compounds were precipitated with basic lead acetate, filtered and redissolved by the removal of lead before estimation. Chlorogenic acid was also estimated in the harvest samples by quantitative paper chromatography, as described by Cruickshank and Swain (8) except for use of the crude ethanolic solution instead of adsorbing the phenolics on carbon for partial purification.

All methods used gave consistent results, but none was completely satisfactory. The total phenolic content as estimated by the Folin-Denis reagent was 2 to 3 times as high as the phenolic content as estimated by the other methods. This method is known to include tyrosine and ascorbic acid as well as any "tannins" that may be present (5, 7, 10).

The method of Arnow (1) was useful since the reagent reacts principally with o-dihydroxyphenols. For routine analyses, a more convenient approximation of the o-dihydroxyphenols (chlorogenic and caffeic acids) was considered to be the absorbence of the crude ethanolic solutions at 325 mμ. The objection to this spectrophotometric method is that compounds other than the o-dihydroxyphenols present in the crude ethanolic solutions may be absorbing light at 325 mμ. This condition may be partially corrected by the method of Weiss (16).

Quantitative paper chromatography of the crude ethanolic solutions was the best method available for the separate estimation of chlorogenic and caffeic acids. Purification of the phenolic solutions by lead precipitation, ethyl acetate extraction or adsorption on charcoal was not completely quantitative since the residual solutions of the potato extracts in most cases showed a detectable base-shift and a positive Folin-Denis test. The principal objections to the quantitative paper chromatography of the phenolic compounds were (a) in many runs the recovery of the standard sample of chlorogenic acid after paper chromatography was not complete and (b) it was necessary to overload the papers to obtain even traces of caffeic acid.

### Evaluation of After-Cooking Darkening

The corresponding halves of each tuber analyzed for phenolic content were boiled for 25 minutes in distilled water in glass containers. After boiling, the tubers were exposed to the air for 1 hour and visually rated for discoloration.

## Results

### Qualitative Identification

Six major components and numerous minor blue fluorescent spots were distinguishable under ultraviolet light in the two-dimensional chromatograms of the ethyl acetate extract from Russet Rural tubers (Figure 1.). Spots 3 and 5 (Figure 1) were the only components that reacted with ferric chloride and gave positive tests for o-dihydroxyphenols. Spot 5 fluoresced blue in ultraviolet light and yellow-green after exposure to ammonia vapor. These properties were suggestive of chlorogenic acid. The two-dimensional sheets were used as a guide in the identifications and serve to show the complexity of the blue-fluorescing compounds present in Russet Rural tubers.

The one-dimensional sheets developed with 5 per cent aqueous acetic acid showed 4 prominent blue-fluorescent bands with $R_F$ values of .19, .35, .67 and .80. These were designated as bands 1, 2, 3, and 4, respectively. Identification of bands 2 and 3 will be reported since these were the only two reacting with ferric chloride.

Band 2 separated into 3 components, all of which reacted with ferric chloride on chromatography in aqueous solvent systems. On the basis of further chromatography (Table 1) and spectroscopic information (Table 3) it was established that band 2 consisted of dual spots of caffeic acid, presumably cis- and trans-isomerides, and a third component resembling esculetin. It is believed that the component resembling esculetin was an artifact of chromatography since it was formed during repeated chromatography of authentic caffeic acid in aqueous solvent systems.

Band 3 separated into 2 components on chromatography with n-butanol-pyridine-water (10:3:3) as the solvent. The one component (band 3.1) which reacted with ferric chloride was established as chlorogenic acid (Tables 2 and 3).

The two-dimensional chromatograms of the ethyl acetate extract of Kennebec tubers differed from those of Russet Rural in that two additional spots were present; these reacted with ferric chloride and became a deep yellow upon exposure to ammonia fumes. These additional spots appeared to be flavonoid compounds.

### Quantitative Estimation

The phenolic content of the tubers at harvest showed considerable variation, the amount depending on the method of analysis and the portion of the tuber analyzed (Table 4). Total phenolic content as estimated by the Folin-Denis reagent was higher in both varieties than the phenolic content as estimated by other methods more specific for the o-dihydroxyphenols. The cortex tissue of both varieties showed a higher phenolic content than the pith tissue. Total phenolic content as estimated by the Folin-Denis

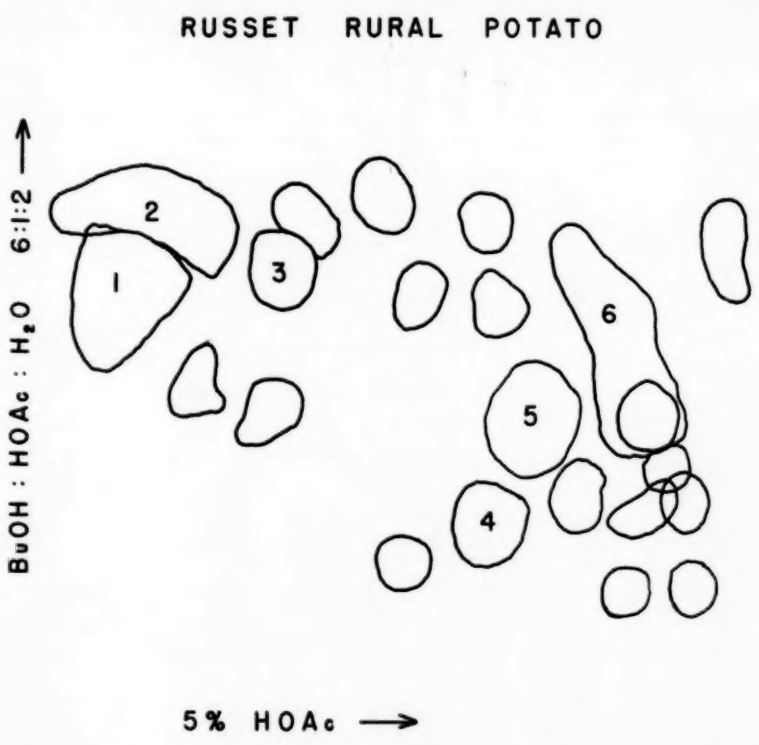


FIGURE 1.—Diagram of a two-dimensional paper chromatogram of the ethyl acetate extract from Russet Rural potatoes showing the blue fluorescent areas. The 6 most prominent spots are numbered. Only spots 3 and 5 gave positive tests for o-dihydroxyphenols.

TABLE 1.—*$R_F$ values and movement by paper electrophoresis of band 2 from extract of Russet Rural potatoes and authentic esculetin and caffeic acid.*

| Band or Compound | $R_F$ Values in— | | | | | Mm movement in 3 hours in pH 7 borate buffer |
|---|---|---|---|---|---|---|
| | $H_2O$ | 5 per cent HOAc-$H_2O$ | n-BuOH-HOAc-$H_2O$ (6:1:2) | m-cresol-HOAc-$H_2O$ (50:2:48) | i-PrOH $H_2O$ (1:4) | |
| Band: | | | | | | |
| 2.1 | .33 | .44 | .79 | .76 | .56 | 81 |
| 2.2 | .33, .62, .96 | .33, .44, .69 | .83 | .32, .51, .76 | .55, .90 | 83, 156 |
| 2.3 | .33, .62, .96 | .34, .45 | .78 | .74 | .55, .89 | 85, 157 |
| Authentic compounds: | | | | | | |
| Esculetin | .33, .44 | .44 | .78 | .75 | .56 | 84 |
| Caffeic acid | .34, .69 | .34, .69 | .84 | .33, .50 | .89 | 157 |

TABLE 2.—*$R_F$ values and movement by paper electrophoresis of band 3.1 and its saponification products from extract of Russet Rural potatoes and authentic chlorogenic, caffeic and quinic acids.*

| Band or Compound | R6 Values in— | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | n-BuOH-HOAc-$H_2O$ (6:1:2) | m-cresol-HOAc-$H_2O$ (50:2:48) | 73 per cent Phenol-$H_2O$ | 5 per cent HOAc-$H_2O$ | $Et_2O$-HCOOH-$H_2O$ (50:20:10 | s-BuOH-HCOOH-$H_2O$ (34:2:4) | n-BuOH-HCOOH-$H_2O$ (4:1:5) | EtOAc-HCOOH-$H_2O$ (10:2:3) | Mm movement in 4 hours in pH 7 borate buffer |
| Band 3.1 | .68 | .33 | .67 | .80, .88 | | | | | 51 |
| Saponified band 3.1: | | | | | | | | | |
| ETOAc phase | .88 | .85 | .89 | .49, .78 | | | | | |
| Aqueous phase | | | | | .54 | .28 | .35 | .24 | |
| Authentic compounds: | | | | | | | | | |
| Chlorogenic acid | .67 | .32 | .67 | .79, .88 | | | | | |
| Caffeic acid | .88 | .85 | .90 | .50, .80 | | | | | 51 |
| Quinic acid | | | | | .54 | .29 | .30 | .24 | |

TABLE 3.—*Ultraviolet absorption and fluorescent spectra of methanolic solutions of bands separated from extract of Russet Rural potatoes and authentic chlorogenic and caffeic acids.*

| Band or Compound | Ultraviolet Absorption | | Fluorescent λ Max. | | |
|---|---|---|---|---|---|
| | Max. | Min. | Before Spectral Shift | With $AlCl_3$ | With $AlCl_3$ +NaOAc |
| Band: | mμ | mμ | mμ | mμ | mμ |
| 2.2 | 325 | 265 | 440 | 470 | 490 |
| 3.1 | 330 | 269 | 440 | 450 | 505 |
| Authentic compounds: | | | | | |
| Caffeic acid | 326 | 264 | 440 | 470 | 490 |
| Chlorogenic acid | 330 | 268 | 440 | 450 | 505 |

TABLE 4.—*Phenolic content of Russet Rural and Kennebec potatoes at harvest as influenced by method of analysis and portion of tuber analyzed.*

| Procedure for Analysis | Phenolic Content Calculated as Chlorogenic Acid in 100 Gms. (Fresh Weight)[1] | | | | | |
|---|---|---|---|---|---|---|
| | Russet Rural | | | Kennebec | | |
| | Whole Tuber | Cortex | Pith | Whole Tuber | Cortex | Pith |
| | Mg | Mg | Mg | Mg | Mg | Mg |
| Folin-Denis | 39 | 44 | 32 | 59 | 68 | 47 |
| Arnow | 18 | 20 | 7 | 23 | 27 | 7 |
| Optical density at 325 mμ | 16 | 19 | 5 | 20 | 24 | 6 |
| Method of Weiss | 12 | 15 | 3 | 14 | 17 | 4 |
| Purification by lead precipitation | 20 | 24 | 10 | 27 | 38 | 12 |
| Paper chromatography: Chlorogenic acid | 8 | 12 | 2 | 9 | 11 | 2 |

[1]Means of triplicate determinations on 3 ten-tuber samples.

reagent did not show the same proportionate drop between cortex and pith tissues as the phenolic content estimated by methods more specific for o-dihydroxyphenols. The Kennebec variety was higher in total phenolic content than the Russet Rural variety. This can be explained in part by the presence of the additional reactive compounds, presumably flavonoids, in the Kennebec variety. Both varieties had similar levels of o-dihydroxyphenolic compounds in the pith tissue.

It was not possible to obtain a reliable estimate of the caffeic acid content of the potato tubers other than to determine that this acid was present in amounts much smaller than chlorogenic acid. Results from quantitative paper chromatography indicated that there was at least 8 to 10 times as much chlorogenic acid as caffeic acid in both the cortex and

the pith tissue of both varieties. The best estimate of the content of chlorogenic acid in the Russet Rural tubers was 15 mg. or less/100gm. (fresh weight) of cortex tissue and 3 mg. or less/100 gm. (fresh weight) of pith tissue. These values are lower than those reported by workers for different varieties (9, 11).

The total phenolic content as estimated by the Folin-Denis reagent and the o-dihydroxyphenolic content as estimated by the optical density at 325 mμ were determined at monthly intervals in tubers of Russet Rural and Kennebec potatoes stored for 5 months at 55°, 40° and 32° F. (Table 5). The total phenolic and o-dihydroxyphenolic contents did not change significantly in either variety during 5 months of storage at 55° and 40° or 3 months of storage at 32°. After 4 months of storage at 32° both varieties showed evidence of low-temperature injury similar to that shown for Kennebec tubers in figure 2 and the total phenolic and o-dihydroxyphenolic contents showed small but significant increases. From the work of Johnson and Schaal (10), it would appear that these increases were not responses to storage temperature, but were related to the injury.

The optical density at 280 mμ of the crude ethanolic extracts of Russet Rural and Kennebec potatoes did not change significantly during the storage of the tubers for 5 months at 55°, 40° and 32° F. The general

TABLE 5.—*Phenolic content of Russet Rural and Kennebec potatoes during storage at 55°, 40° and 32° F.*

| Storage Temp. (°F) and Period | Phenolic Content Calculated as Chlorogenic Acid in 100 Gms. (Fresh Weight)[1] | | | |
|---|---|---|---|---|
| | Russet Rural | | Kennebec | |
| | By Folin-Denis Reagent | By Optical Density at 325 mμ | By Folin-Denis Reagent | By Optical Density at 325 mμ |
| | Mg | Mg | Mg | Mg |
| 55°: | | | | |
| 1 month | 38 | 12 | 52 | 20 |
| 2 months | 36 | 13 | 58 | 23 |
| 3 months | 34 | 14 | 60 | 19 |
| 4 months | 42 | 16 | 57 | 20 |
| 5 months | 39 | 12 | 58 | 21 |
| 40°: | | | | |
| 1 month | 41 | 14 | 58 | 24 |
| 2 months | 35 | 15 | 54 | 20 |
| 3 months | 38 | 13 | 58 | 19 |
| 4 months | 39 | 12 | 60 | 23 |
| 5 months | 40 | 16 | 56 | 22 |
| 32°: | | | | |
| 1 month | 36 | 16 | 57 | 19 |
| 2 months | 36 | 14 | 54 | 21 |
| 3 months | 42 | 18 | 61 | 22 |
| 4 months | 47 | 24 | 74 | 26 |
| 5 months | 51 | 30 | 85 | 36 |
| L.S.D. (5 per cent) | 7 | 6 | 11 | 7 |

[1]Means of 8 individual tuber halves.

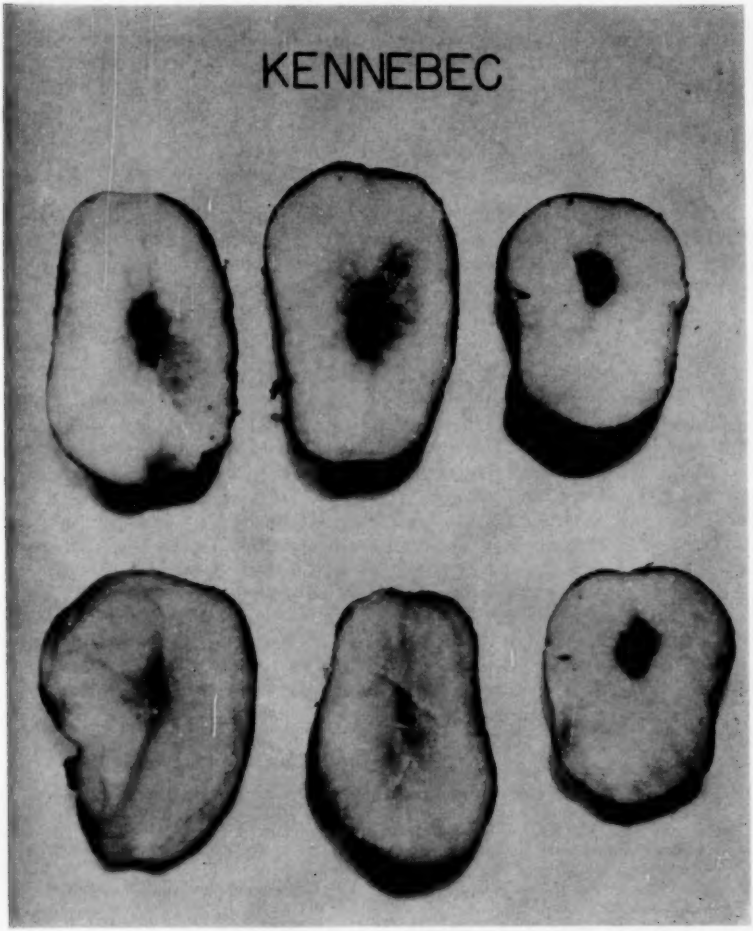


FIGURE 2.—Low temperature injury in Kennebec potato after 4 months at 32° F.

behavior of the absorption curve below 300m$\mu$ of the crude extracts was similar to that reported by other workers (3, 5) in that the absorption was greater than that which could be attributed to the chlorogenic and caffeic acids present. This increased absorption could not be related to any known phenolics present in the tubers other than tyrosine and probably represented absorption caused by this compound as well as by other aromatic compounds.

Kennebec potato tubers held for 8 days at 96° F. had a mean total phenolic content of 61 mg./100 gm. and a mean o-dihydroxyphenolic content of 21 mg./100 gm. (fresh weight). These values did not differ significantly from the harvest values for total phenols as determined by the Folin-Denis reagent and o-dihydroxyphenols as determined by the optical density at 325 mμ (Table 4).

## After-Cooking Discoloration

After-cooking darkening was not serious in the samples of Russet Rural and Kennebec studied. The only definite darkening that occurred was in the stem end of the Kennebec tubers after 1 month at 55° F. and the amount of discoloration did not increase with storage time.

## Summary

Chlorogenic and caffeic acids were identified in extracts from Russet Rural potatoes by a combination of one- and two-dimensional paper chromatography, paper electrophoresis, ultraviolet spectrophotometry and spectrophotofluorimetry. The best estimate of the content of chlorogenic acid in the Russet Rural tubers was 15 mg. or less/100 gm. in the cortex tissue and 3 mg. or less/100 gm. (fresh weight) in the pith tissue.

The total phenolic content as estimated by the Folin-Denis reagent and the o-dihydroxyphenolic content as estimated by the optical density of the extracts at 325 mμ did not change significantly in Russet Rural and Kennebec potato tubers during 5 months of storage at 55° and 40° or 3 months of storage at 32° F. Both varieties showed evidence of low-temperature injury after 4 months at 32° and the total phenolic and o-dihydroxyphenolic contents showed small but significant increases. It was concluded that this increase was related to the injury present rather than to the storage temperature.

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# POTATO COMMON SCAB INVESTIGATIONS

## II. Five Years of Plot Studies on Soil Reaction Changes and Incidence of Scab as Affected by Limestone and Sulphur Applications on Fox Fine Sandy Loam[1]

T. J. Heeg[2] and J. K. Richardson[3]

### Introduction

Potato common scab is caused by *Streptomyces scabies* (Thaxter) Waksman and Henrici (8). The disease is of economic importance because the lesions on the tubers are unsightly and detract from the appearance of the product. Regardless of other undesirable factors, Government regulations require that 80 per cent of the tubers be free from surface scab and no tuber be infected in excess of five per cent of its surface area (1).

A survey of almost 100 Ontario potato farms during 1948 and 1949 indicated a relationship between soil reaction and potato scab (6). More scab was found in soils having pH values between 6.0 and 7.0 than in soils with a pH range below 5.5. Potatoes in soils above pH 7.5 also had low amounts of scab but were not so clean as those in the low reaction range.

It was evident that soil reaction had an effect on the activity of the scab organism and these conclusions are supported by other investigators (2) (3) (4) (5).

This study was designated to determine scab incidence on potatoes grown on one location at different pH levels induced chiefly by the addition of lime and sulphur.

### Description of Plot Area

The site chosen for the study of various aspects of scab control was a 2½-acre field of Fox fine sandy loam located in Wentworth County near Hamilton which was known to produce very scabby potatoes. The topography was gently rolling and the soil relatively uniform with small differences caused by sheet erosion rather than variations in soil type. Organic matter ranged from 1.5 to 2 per cent. The plots susceptible to erosion were lowest in this constituent. Cation exchange capacity varied between 6.5 and 10 milli-equivalents per 100 grams of soil and was in proportion to the organic matter present.

The greatest variation in the plot area was in soil reaction. Prevailing winds, carrying limestone dust from an adjacent gravel road, had limed the plots in varying degree giving rise to pH values of 7.5 near the road. The reaction decreased gradually until the most distant portion of the field had a pH of 5.5.

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[1]Accepted for publication January 30, 1958.
Contribution from the Department of Soils, Ontario Agricultural College, Guelph, Ontario,—and the Division of Botany and Plant Pathology, Science Service, Department of Agriculture, Ottawa, Canada—a co-operative project carried on under the Ontario Potato Scab Research Committee.

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## Treatments and Methods

The Katahdin variety of potato was used throughout this investigation.

The two rates of limestone, 1000 and 2000 pounds per acre, and sulphur at 500 and 1000 pounds per acre, were broadcast on the plot areas and disced in each spring before planting. The years in which applications were made are shown in table 1.

Representative soil samples were collected from all plots in early May and in late September of each year. pH was determined with a Model G Beckman pH meter using a thin paste of soil and water. At harvest, scab readings were taken on 100 tubers selected at random from the central portion of each plot. The percentage of the surface of each tuber affected by scab was estimated with the aid of a series of mathematically accurate charts (6) and the average was recorded as the scab incidence of the plot.

Table 1.—*Limestone and sulphur treatments on 1/50 acre plots over a five-year period.*

| Treatment Number | Replicates | 1949 | 1950 | 1951 | 1952 | 1953 |
|---|---|---|---|---|---|---|
| 20 | 3 | None | None | None | None | None |
| 28 | 4 | 1000 lb. limestone | 1000 lb. limestone | 1000 lb. limestone | A. None<br>B. 1000 lb. limestone | None<br>None |
| 29 | 4 | 2000 lb. limestone | 2000 lb. limestone | 2000 lb. limestone | A. None<br>B. 2000 lb. limestone | None<br>None |
| 26 | 4 | 500 lb. sulphur | 500 lb. sulphur | 500 lb. sulphur | A. None<br>B. 500 lb. sulphur | None<br>None |
| 27 | 4 | 1000 lb. sulphur | 1000 lb. sulphur | A. None<br>B. 1000 lb. sulphur | A. None<br>B. None | None<br>None |
| 10 | 4 | Soybeans | None | 1000 lb. S. plus 2000 lb. limestone | 1000 lb. S. plus 2000 lb. limestone | None |

## Results and Discussion

The variations in pH of the check plots, treatment 20, is shown in figure 1. In two of the three plots there is a normal fluctuation of approximately 0.5 pH unit from season to season. However, the third plot increased a full pH unit from September 1949 to May 1950, after which variations were of a minor nature. The abnormal increase in pH in this plot in the first year was attributed to erosion caused by heavy rains in the fall and spring of 1949-1950. This plot was located on more of a slope than the others and the B horizon, with higher pH values, was exposed by run-off.

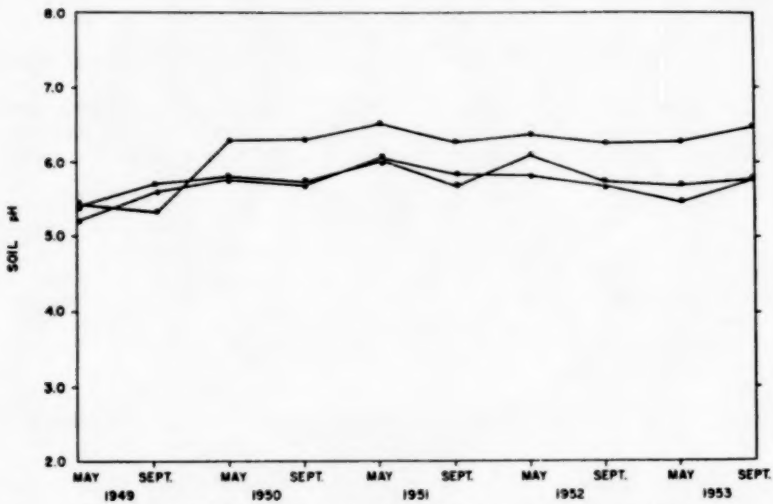


FIGURE 1.—The pH changes in check plots over the five year period.

*Effect of Limestone on pH*

Limestone applied to soils increases pH values though these increases are not so great as would be expected with higher rates of application. The limestone used was a finely ground, high grade calcitic stone, at least 85 per cent passing a 100 mesh screen.

When limestone at 1000 pounds per acre was applied in each spring of three successive years, the greatest increase in pH occurred in the first year. Starting pH values averaged 5.6 and had increased to 6.4 at the end of the first year. There were further increases in the second year, 1950, but in the third year of application the pH did not increase. It remained fairly constant at an average value of 6.6 in the fourth year, 1952, when no additional lime was applied. From the fall of 1952 to the spring of 1953 there was a drop in pH values in all plots, but generally the plots regained some of the loss during the summer of 1953. Average pH values in September 1953 were 6.4.

These same plots were divided in the spring of 1951 and one-half of each plot received an additional 1000 pounds limestone per acre. This fourth application raised pH values slightly from May to September 1952. However, the gain was not maintained from September 1952 to May 1953, though pH values in May 1953 were still about 0.3 higher than the lesser rate of lime application. These slightly higher pH values were maintained at the end of the experiment in September 1953.

Another group of lime plots had 2000 pounds of limestone applied in each spring of the years 1949, 1950 and 1951, and residual effects were measured in 1952 and 1953. Starting pH values averaged 6.0 in these plots. At the end of the first year after the 2000 pounds limestone application the average pH was 6.5 and after the second application it was 7.2.

In the third year of treatment, there was actually a slight decrease in most pH values and these values, averaging 6.9, were more or less maintained to the end of the experiment two years later.

When limestone at the 2000 pounds rate was continued for four successive years, a slight increase in pH occurred in the fourth year. These higher values were reduced only slightly in the fifth year, 1953, when no further lime was added. In general, the final pH figures for the plots receiving a total of four tons in four years, were only slightly higher than for three years of treatment totalling three tons.

The pH values where four applications of 2000 pounds of limestone were made, averaged 6.0 at the start and 7.3 at the end of fourth year. In the plots where four applications of 1000 pounds were applied, the average pH values were 5.6 at the start and 6.5 at the end of the fourth year.

*Effect of Sulphur on pH*

The pH changes which occurred in the plots receiving 500 pounds per acre of sulphur in each spring of the years 1949, 1950 and 1951 are shown in figure 2. A pH reduction of considerable extent was achieved in two plots in the first year. The other two replicates, however, failed to show a decrease until the second year, and one of these two, resisted a marked change until the third year of treatment. It is interesting to note the decrease in pH during the summer and the increase during the winter months. This, of course, can only be caused by the activity of the sulphofying bacteria, oxidizing the sulphur to sulphuric acid during the warm summer months. During the winter the organisms are dormant, so that fall and spring rains together with the melting snows have an opportunity to leach out the sulphuric acid.

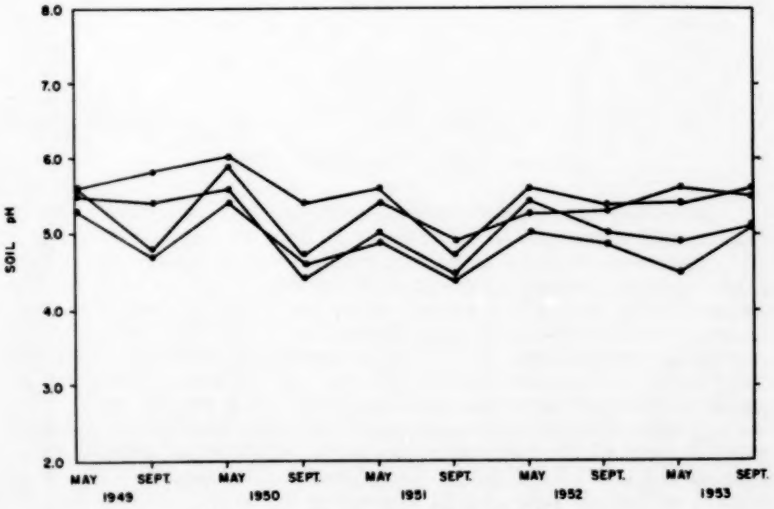


FIGURE 2.—500 pounds sulphur 1949-1951.

In three of the four replicates a minimum pH was reached in the second year of treatment, 1950, with 500 pounds of sulphur per acre. By September 1951 all replicates were below pH 5.0 after 3 successive years of treatment. One year later, in September 1952, pH values increased considerably, and by the end of 1953 there was little difference between the 1949 original and final 1953 pH values. Leaching, along with buffer capacity enabled the soil to regain its original pH two years after these treatments were stopped.

The effect of four successive yearly treatments with 500 pounds of sulphur per acre is shown in figure 3. As might be expected the fourth treatment in 1952 maintained the low pH values of 1951. When no sulphur was applied in 1953, pH values increased but did not regain the original levels of 1949.

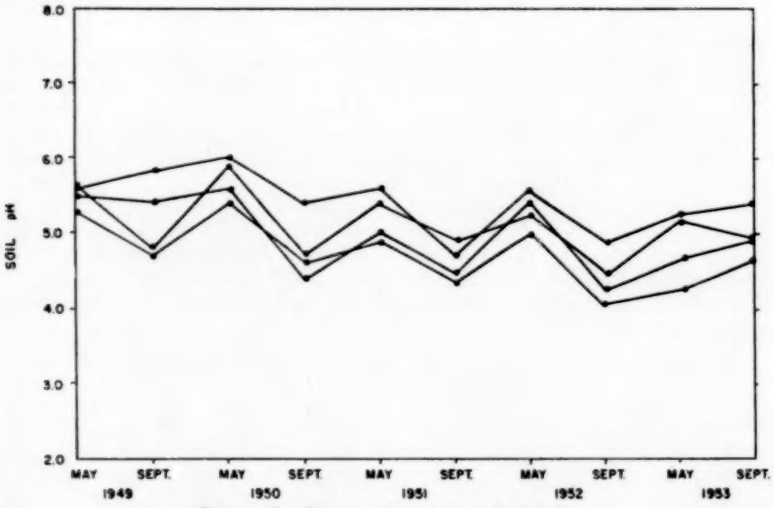


FIGURE 3.—500 pounds sulphur 1949-1952.

The pH values obtained from two successive years of sulphur application at 1000 pounds per acre are shown in figure 4. Marked decreases in pH occurred in all plots in the first year, and a further decrease during the second year. During the winter of 1949-1950 pH values rose to near the original levels, but in the second winter they did not recover so well. When no sulphur was applied in 1951 pH values remained about stationary at the spring values of that year. During the winter of 1951-1952 soil reaction rose to values close to the originals. There was some reduction in pH in 1952 but all plots increased in pH during the summer of 1953, —three years after sulphur applications were discontinued. It should be noted that one plot had a starting pH of 6.1 compared with starting values between 5.2 and 5.5 for the remaining three. This higher pH plot never reached as low pH values as the others, and its rate of pH increase after treatments were discontinued, was greater. Soils of higher pH require

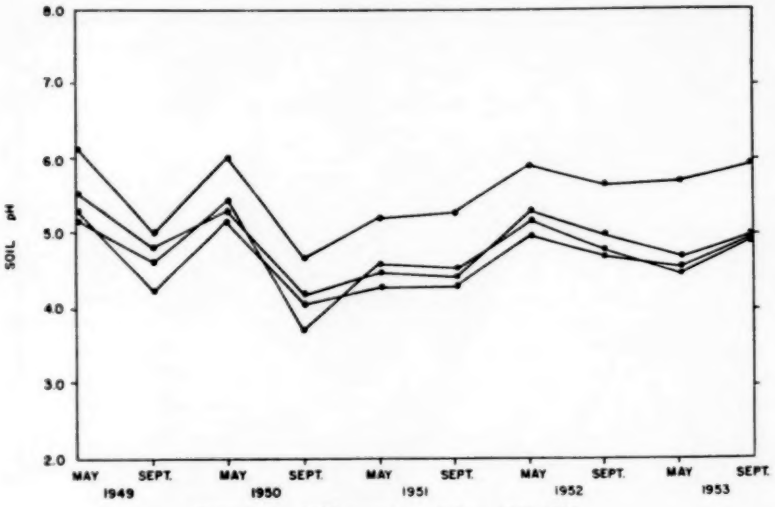


FIGURE 4.—1000 pounds sulphur 1949-1950.

more sulphur to lower their pH value and to maintain a low value over a period of time.

The pH changes occurring with three successive sulphur applications of 1000 pounds per acre each appear in figure 5. It will be seen that the pH values for September 1951 are substantially similar to those of September 1950. Therefore, the additional 1000 pounds of sulphur served to maintain the low levels of the previous year. The residual effect one year after in 1952, was about the same as for two 1000 pounds sulphur applications one year later. The sulphur was losing its influence in 1953, when three of the four replicates increased in pH from May to September, the period in which acidity should increase if much residual sulphur remained.

*Limestone and Sulphur*

Two years after this experiment was in progress, the idea arose that limestone applied with sulphur would help control the excess acidity.

It is recognized that 1000 pounds of sulphur would require 3125 pounds of limestone to correct the resultant acidity formed. The idea was to apply sufficient sulphur to produce strong acidity which would control scab, and yet be tempered sufficiently by the limestone to allow normal soil processes of nitrate production to proceed and thus not impair yields.

Therefore, in each spring of the years 1951 and 1952 one ton of limestone and 1000 pounds of sulphur were applied. The changes in pH of the replicated plots for this treatment are shown in figure 6. The pH values decreased sharply during the summer but increased during the winter in both years of treatment. In 1953, when no further application was made, pH values rose in three of four plots, indicating a stronger

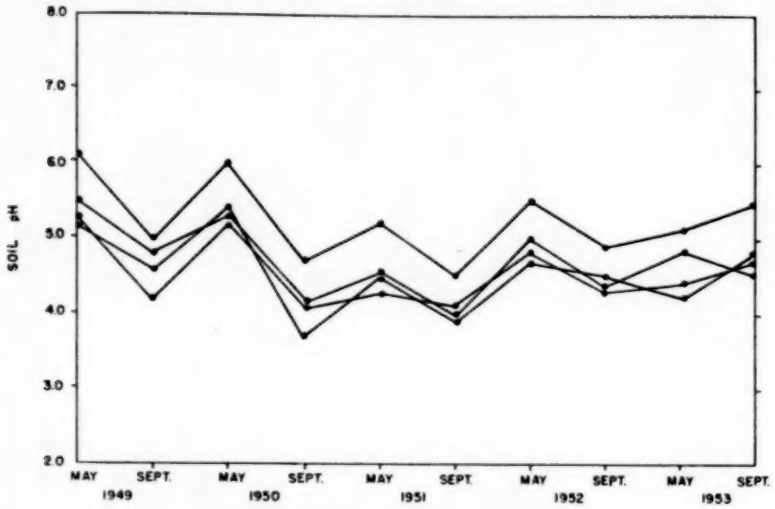


FIGURE 5.—1000 pounds sulphur 1949-1951.

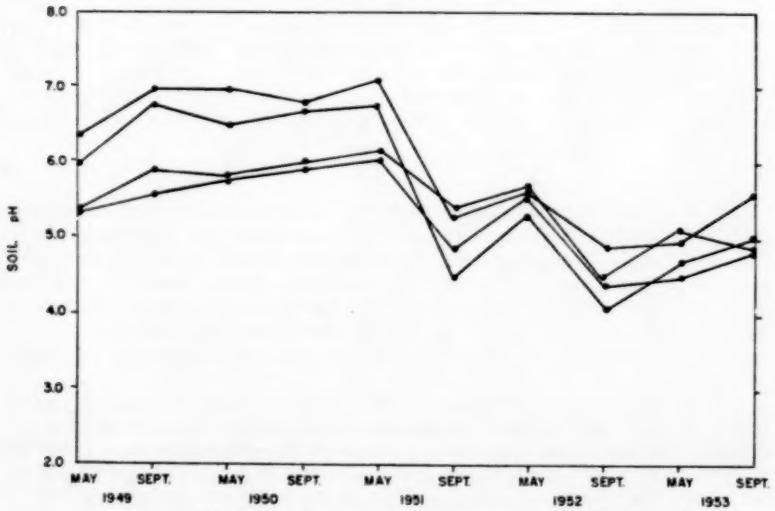


FIGURE 6.—2000 pounds limestone + 1000 pounds sulphur 1951-1952.

residual effect for limestone than for sulphur. In treatments where sulphur was applied without limestone, usually the pH decreased again in the first residual year but tended to increase in the second.

*Relationship between pH and Per Cent Scab*

In the check plots (Figure 7) potato scab increased sharply from the first year to the second year and the high scab incidence was maintained over the remaining years of the experiment. One of the check plots increased in pH from 5.3 to 6.3 and scab in this plot increased from 41 to 59 per cent. The other two check plots remained relatively uniform in pH during the first two years and yet scab increased from 23 to 47 per cent in one plot, and from 18 to 53 per cent in another. The high scab readings in all three plots appear to bear no relationship to changes in pH. However, the data indicate that scab increases when potatoes are grown in the same location, and that a peak scab incidence is reached which appears to become relatively stabilized.

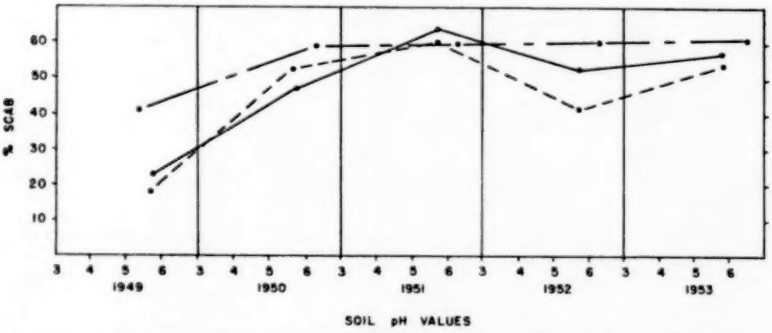


FIGURE 7.—Relationship between common scab of potatoes and pH of the soil in check plots over the five-year period.

*Limestone and Scab*

Limestone applications at either 1000 or 2000 pound rates applied each year for three and four years had little effect either in the reduction or increase of scab as shown in table 2. The scab pattern, in general, was similar to that of the check plots. There was a considerable increase in scab incidence in the second year on all lime plots, though the increase was greater for the 1000 pound rate. The 2000 pound rate of lime showed an average scab reduction over the check plots in the year 1951 from 61 to 48 per cent, as shown in table 2. These average figures also show a reduction in 1952 and 1953. In no case do these reductions represent satisfactory control of scab, therefore too much emphasis should not be placed on them.

In 1952 the lime plots were split so that one-half received an additional treatment and the other received no further lime. Scab readings increased in the plots receiving additional lime at both the 1000 and 2000 pound rates in 1952. In 1953, the residual effect of four limestone applications of 2000 pounds gave lower scab readings. Because these results are so variable and inconsistent and because reductions in scab,

TABLE 2.—*Averages for common potato scab in percentage and yields of potatoes in bushels per acre for plots receiving sulphur or lime treatments.*

| Treatment Number | Treatment | 1949 | 1950 | | 1951 | | 1952 | | 1953 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Scab Per cent | Scab Per cent | Yields Bus./A. | Scab Per cent | Yields Bus./A. | Scab Per cent | Yields Bus./A. | Scab Per cent | Yields Bus./A. |
| 20 | Check plots No treatment | 27 | 53 | 445 | 61 | 353 | 52 | 260 | 57 | 277 |
| 28A | 1000 lb. limestone for 1st 3 years | 28 | 62 | 406 | 55 | 304 | 49 | 245 | 47 | 248 |
| 28B | 1000 lb. limestone for 1st 4 years | 28 | 62 | 406 | 55 | 304 | 58 | 237 | 54 | 267 |
| 29A | 2000 lb. limestone for 1st 3 years | 29 | 53 | 429 | 48 | 303 | 41 | 287 | 45 | 308 |
| 29B | 2000 lb. limestone for 1st 4 years | 29 | 53 | 429 | 48 | 303 | 44 | 270 | 31 | 261 |
| 26A | 500 lb. sulphur for 1st 3 years | 22 | 16 | 408 | 3 | 312 | 13 | 290 | 14 | 316 |
| 26B | 500 lb. sulphur for 1st 4 years | 22 | 16 | 408 | 3 | 312 | 4 | 279 | 10 | 296 |
| 27A | 1000 lb. sulphur for 1st 2 years | 17 | 4 | 364 | 4 | 372 | .. | .. | 28 | 282 |
| 27B | 1000 lb. sulphur for 1st 3 years | 17 | 4 | 364 | 0.4 | 239 | .. | .. | 3 | 332 |
| 10 | 2000 lb. limestone + 1000 lb. sulphur in 1951 and 1952 | .. | 44* | 436* | 22 | 338 | 8 | 294 | 14 | 290 |

*Readings prior to treatment

where noted are not great, it is felt that no conclusions can be drawn on the value of lime for scab control.

*Sulphur and Scab*

In the plots receiving sulphur at the 500 pound rate, the starting pH values of the soil in May, 1949, were very similar ranging from 5.3 to 5.6, as revealed, in figure 2. In an effort to relate the maximum effect of treatment, the pH values shown on the graphs are those of September in each year. When sulphur was used, potato scab was not controlled until pH fell below 5.0 (Figure 8). Control was not definite, however, until the third year of application of sulphur at the 500 pound per acre rate. Both potato scab and pH values increased slightly in the fourth and fifth years when no sulphur was applied.

The effect of a fourth 500 pound per acre sulphur application is shown in figure 9. In 1952, it is seen that pH values and scab readings are as low as in 1951. In 1953 no sulphur was applied and there was better residual effect of the sulphur than was the case with three applications.

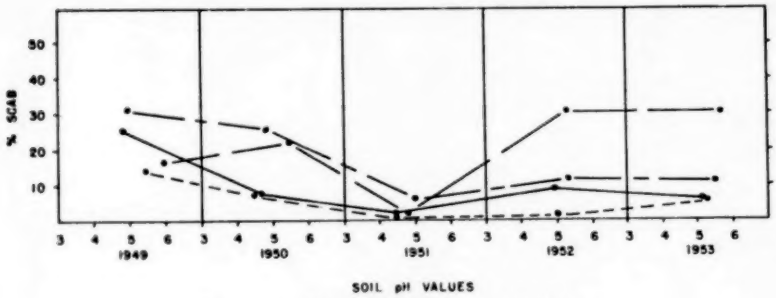


FIGURE 8.—500 pounds sulphur 1949-1951.

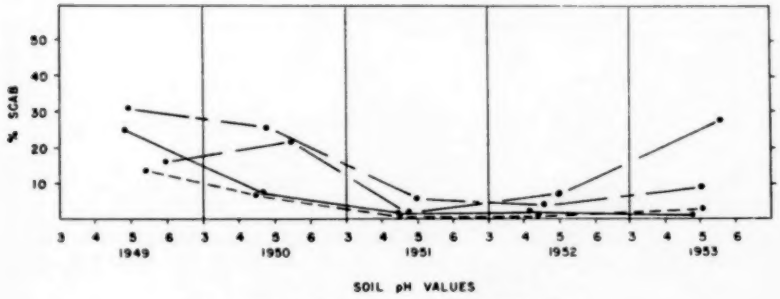


FIGURE 9.—500 pounds sulphur 1949-1952.

However, in this year, one of the four plots showed little effect from the four sulphur treatments.

Sulphur at the rate of 1000 pounds per acre was applied in the spring of two successive years, 1949 and 1950 (Figure 10). In the third year the plots were divided and to each one-half plot a third treatment of 1000 pounds was made (Figure 11).

The pH values of these plots in the spring of 1949 when the experiment was started were 5.2, 5.3, 5.5 and 6.1 (Figure 4). The highest scab reading in 1949 was from the plot with a starting pH value of 6.1, whereas the second highest was from the 5.5 soil. Scab readings for the year 1952 (Figures 10 and 11) are missing because of a harvesting error.

It is evident that a greater reduction in scab took place in 1949, the first year of application, than was the case with the 500 pound rate (Figure 8). In 1950 scab was practically controlled as shown in figure 10. The plot with a starting pH of 6.1 gave a scab reading of 8 per cent in this year, and the soil pH was reduced to 4.7. Scab in the other three plots was less than 5 per cent. The 1951 scab readings remained low in three of the four replications. pH values for these three plots, although slightly higher in 1951, were still 4.5 or below. Since no sulphur was applied to these plots in 1951, a good residual effect is indicated. However, scab was not held in check in the plot with the higher starting pH (6.1). The

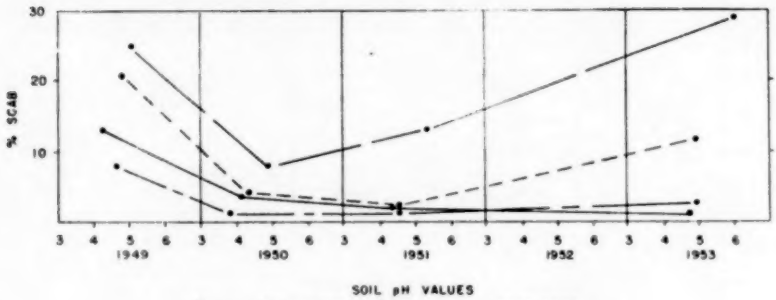


FIGURE 10.—1000 pounds sulphur 1949-1950.

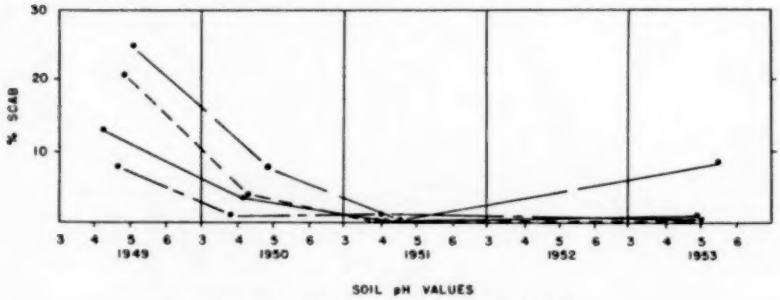


FIGURE 11.—1000 pounds sulphur 1949-1951.

pH rose to 5.3 in 1951 from the 4.7 level in 1950 and scab increased from 8 per cent in 1950 to 13 per cent in 1951, indicating again that effective control can be expected only when pH values are below 5.0.

In 1953, two plots were still low in scab incidence, despite the fact that three years had elapsed since the last sulphur application. The two higher scab readings were in soils of higher starting pH.

In the third year, 1951, after three successive applications of 1000 pounds sulphur per acre, scab had been practically eliminated from all replicates. The residual effect of the sulphur was plainly evident in 1953, two years after the treatment was discontinued. The only plot showing a higher scab reading (9 per cent) was the one having a higher starting pH value (6.1). The pH rose in this plot from 4.5 in 1951 to 5.5 in 1953. These data again emphasize the fact that pH values below 5.0 are necessary for effective scab control.

*Limestone and Sulphur*

In 1951, four plots were treated with 2000 pounds per acre of limestone and 1000 pounds per acre of sulphur. This was repeated in 1952 with no further treatment in 1953.

The results show that scab was reduced in 1951 but not controlled (Figure 12). In 1952, two plots had less than 5 per cent scab whereas two others showed 11 and 12 per cent respectively. The treatment can therefore be looked upon somewhat favorably, but is not as good a control measure for potato scab as 1000 pounds per acre of sulphur alone. Particularly was this so when the 1953 scab readings are considered. The residual effect was not good when one of the four replicates had a scab incidence of 23 per cent whereas the others were 9 per cent or above.

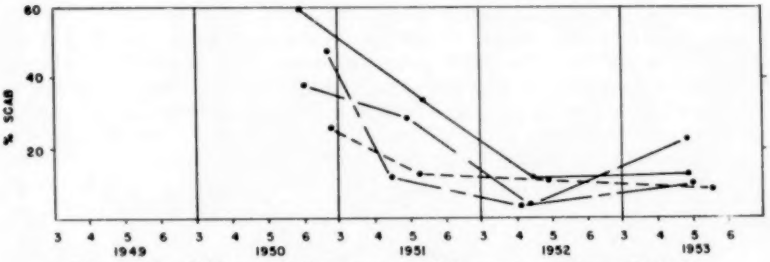


FIGURE 12.—2000 pounds limestone + 1000 pounds sulphur 1951-1952.

*Yields of Potatoes in Relation to Treatment.*

In addition to the treatments discussed, all plots were given an annual application of 1000 pounds per acre of 4-12-10 fertilizer. Fall rye was sown each October and plowed in before planting time in May. Despite these treatments, yields, in general, were not high. No yields were taken in 1949 but data are available for the years 1950 to 1953, with the exception of the 1000 pounds per acre sulphur treatment in 1952, when a sampling error occurred in these plots.

There was little difference in yields for various treatments of limestone compared with the check (Table 2) and the 500 pound per acre sulphur treatment continued for two and three years did not affect yields greatly.

In 1950, the second year of 1000 pound per acre sulphur application, average yields were 81 bushels less than the check. In one replicate where soil pH was 4.7, the yield was 444 bushels per acre compared with an average of 445 bushels in the check plots where pH values were in the 5.5-6.5 range. However, in the other three replicates, with pH values of 4.1 and below, the yields were substantially decreased to 343, 365 and 305 bushels per acre. The lowest yield of 305 bushels was in a plot with pH 3.7. In the years 1951 to 1953 when no further sulphur was applied yields were as good as, or better than, the check plots.

In 1951 a third application of 1000 pounds per acre of sulphur was made on part of these plots. Yields were greatly reduced compared with checks with the exception of one plot, the pH of which was 4.5, and the yield 337 bushels. The pH and yield data of the other three plots were respectively 4.1 and 172, 4.0 and 286, and 4.0 and 160 bushels per acre. The low yields in these plots were primarily due to poor germination, and consequent poor stand of plants per plot. However, those plants which did

survive were somewhat dwarfed and chlorotic. By 1953, two years after treatment ceased, yields were as good as those in the check and pH values were 4.5 to 5.5. A study of yield data in relation to pH indicates that yields are impaired when soil pH approaches 4.0.

*Summary.*

1. Normal pH fluctuations in check plots over a five-year period were of the order of 0.5 unit.

2. Limestone applications increased soil pH, but the increase was not in proportion to the amount used.

3. Sulphur applications definitely increased soil acidity and this increase was more or less proportionate to the amount applied. pH values decreased during the summer but increased again over winter. At higher rates of sulphur application, the winter pH increase was not so great as the summer decrease. When sulphur applications were discontinued pH values gradually increased to original levels. This required from one to three years, depending upon the amount of sulphur applied and the starting pH of the soil. The less sulphur used, or the higher the original soil pH, the more quickly the soil returned to its normal pH.

4. Limestone applied, together with sulphur, at rates encouraging the influence of the latter, decreased soil pH almost as much as sulphur alone in the year of application. However, the residual effect of the limestone was stronger than that of the sulphur, resulting in a more rapid return to the soil's original pH value after treatments were discontinued.

5. When potatoes were grown continuously in the rotation without treatment (check plots) scab increased in the first few years to a maximum which was more or less stationary thereafter.

6. Various rates of limestone had little effect on scab incidence which was high at the beginning of the experiment.

7. Sulphur applications adequately controlled potato scab when sufficient was used to lower soil pH below 5.0. The residual influence of sulphur, after applications stopped, was contingent on the soil remaining at pH values below 5.0. A higher starting pH in the soil resulted in less residual influence of the sulphur on scab.

8. Combined sulphur and limestone applications, at the rates used in this experiment, reduced scab considerably but were not an absolute control.

9. Yields of tubers compared with check plots in any particular year were not greatly influenced by limestone, but were by high rates of sulphur applications. When soil pH approached 4.0, yields were reduced but if pH values remained above 4.5 there appeared to be no yield reduction.

## Conclusions

Limestone applications did not appear to increase the area of the tuber covered by scab but the treatment appeared to favor the development of the pathogen as evidenced by the profuse sporulation present on many of the lesions.

Sulphur will control potato scab but will also reduce yields if used in excess. When it is used, it should be done with the co-operation of soil testing services, and frequent checks made on pH levels.

On the basis of this experiment, one year's application of sulphur reduced scab but applications in two successive years were necessary to control it. This means that the use of sulphur in scab control is feasible only to growers who plant potatoes in the same location continuously. The treatment would involve two years of sufficient sulphur to reduce pH to values between 4.5 and 5.0 and then smaller annual applications for maintenance of these values.

In the interests of sound agronomic practice, potatoes should be grown in rotation where sod appears at least once in four or five years. Low pH values are not conducive to the growth of soil improving legumes. In such cases, therefore, sulphur cannot be recommended. In addition, even though growers practice a rotation of continuous potatoes, the treatment is costly and would at least drastically reduce profits, if not eliminate them. Before sulphur is used ,therefore, these points should be carefully considered.

## Acknowledgments

The authors wish to convey their appreciation to members of the Ontario Potato Scab Research Committee for helpful suggestions and constructive criticism received during the progress of this investigation.

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# THE STORAGE OF POTATO POLLEN[1]

H. W. HOWARD[2]

Storage of pollen can be very useful in a potato breeding program because it avoids the necessity of having the two parents required for a cross being in flower at the same time. If the male parent flowers first, then storage of pollen for one, or possibly two months only is needed; but if the female parent flowers first, then storage of from eleven months to one year will be required.

The early work of Kesseler (4) and Kawakami (3) suggested that potato pollen stored under relatively dry conditions (15-20 per cent relative humidity) will remain viable for a period of between ten and fourteen days. Beamish (1) found that deterioration of pollen viability was less rapid under refrigeration than at room temperature, and recently King (5) has indicated that pollen can be stored at —30° F. (—34° C.) for about a year without losing its viability. The successful pollination results reported by King (5) were, however, few, and it therefore seems to be of some value to give further results, obtained in a breeding program, of successful storage of potato pollen for about eleven months.

## METHODS

Anthers were cut off from flowers with a small pair of scissors. They were placed in half petri dishes and dried for about seventeen hours (overnight) either in an oven at 30° C. or in a vacuum dessicator containing a silica gel at room temperature. Both methods of drying anthers appeared to be equally successful. The dried anthers and pollen were placed in small glass tubes which were plugged with cotton wool. Only one storage temperature, —20° C. (—4° F.), was used, and it should be noted that this is considerably higher than the temperature, —34° C. (—30° F.), used by King for successful storage for one year.

Viability of pollen was determined solely by using it to make crosses since there is no suitable artificial medium known for the germination of potato pollen King (5).

## RESULTS

It should be emphasized that the results given in table 1 were obtained not from planned experiments on potato storage but from crosses carried out as part of a breeding program. Thus the relatively large number of results obtained using Ulster Premier as a male parent are due to the fact that in 1957 no fresh pollen of this variety was available early in the season and stored pollen therefore had to be used.

It can be seen from the results in table 1 that the number of seeds obtained shows considerable variation from berry to berry both when fresh and when stored pollen is used. Considering all the results together, however, there is conclusive evidence that storage at —20° C. can maintain the viability of potato pollen for at least eleven months (the 1956 pollen

[1]Accepted for publication January 15, 1958.
[2]Plant Breeding Institute, Trumpington, Cambridge, England.

was dried in July; most of the 1957 pollinations were made in June). Also since viability has been preserved for four varieties (Ulster Knight, Ulster Premier, Ulster Prince and Clarke 650), it would appear that the pollen of all varieties producing large amounts of good pollen can be stored for at least eleven months.

TABLE 1.—*Seeds per berry from 1957 pollinations using stored (1956) and fresh (1957) pollen.*

| Female Parent | Male Parent | Type of Pollen[1] | Number of Seeds per Berry | Average No Seeds/Berry |
|---|---|---|---|---|
| Ackersegen | Ulster Knight | S | 193, 118, 135, 112 | 139.5 |
| " | " | F | 127, 95, 80, 90, 147 | 107.8 |
| Shamrock | Clarke 650[2] | S | 122, 132 | 127 |
| X 7/23[3] | Ulster Premier | S | 127 | 127 |
| Y 12/37[3] | Ulster Premier | S | 81, 81, 54 | 72 |
| " | " | F | 58, 22, 35, 61, 60 | 47.2 |
| Y 15/139[3] | Ulster Premier | S | 110, 106, 88, 119 | 105.8 |
| " | " | F | 97, 64, 106, 160 | 106.8 |
| " | " | F | 138, 122, 130, 160, 130 | 136 |
| " | Ulster Prince | S | 61, 79, 101, 77 | 79.5 |
| " | " | F | 116, 110, 124, 170 | 130 |
| NY 24/7[3] | Ulster Premier | S | 134, 135, 210, 197 | 169 |
| " | " | F | 113, 112, 108, 73 | 101.5 |

[1]Type of pollen — S = stored from 1956, about 11 months old; F = fresh, direct from anthers of flowers which had been open for two days.
[2]Clarke 650 — a pollen fertile seedling from the cross Arran Cairn x Herald, bred by Mr. John Clarke, the breeder of the Ulster series of varieties.
[3]X 7/23, Y 12/37, Y 15/139 and NY 24/7 -- seedlings bred for resistance to root eelworm from *Solanum tuberosum* sub sp. *andigenum* clones C.P.C. 1673, 1685, and 1690 see Cole and Howard (2).

## DISCUSSION

There would not appear to be much improvement possible in either the initial drying of the anthers or in the subsequent storage. One small labor-saving detail is to dry the anthers in the tubes in which they are to be stored instead of in dishes. In addition to saving time there is also less loss of pollen in this method since no pollen is left sticking to the sides of the dishes. It is also convenient to include in each tube just enough anthers for one day's pollinations.

Since both —34° C. used by King (5) and —20° C. used in the present investigations gave successful storage of pollen for one year, it is possible that storage at a higher temperature such as —10° C. would also be successful. Storage at a higher temperature would, however, appear to be of academic interest only because the usual temperature of a deep freeze is about —20° C.

The success of pollen storage for eleven months suggests that storage for two or even three years without appreciable loss of viability may be possible. It is intended to investigate this possibility in 1958 and 1959, supplies of the 1956 Ulster Knight pollen having been retained after the 1957 pollinations.

SUMMARY

The pollen of four varieties of potatoes has been stored successfully at —20° C. (—4° F.) for eleven months. The viability of this stored pollen was tested by using it to make crosses. The stored pollen produced when used in hybridizations, as many seeds per berry as fresh pollen.

ACKNOWLEDGMENT

Many thanks are due to the Director of the Low Temperature Research Station, Cambridge, for permission to store the pollen samples in a chamber at —20° C.

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## NEWS AND REVIEWS

### BOOK REVIEW

POTATO IN WEST BENGAL, by H. C. CHOUDHURI, Special Officer (Potato) Government of West Bengal, Calcutta, India. Published by the Home (Publicity) Department for the Directorate of Agriculture, Govt. of West Bengal, India. Price—9 shillings, 9 pence.

This book, by Dr. Choudhuri explains in a brief and concise manner, the accepted method of producing potatoes in West Bengal. Recommendations for storage, disease and insect control, varieties and marketing are presented so that potato growers as well as students may understand the potato industry, and how to produce and market the crop.

The book is well illustrated with especially good illustrations of several potato diseases and insect pests. Well prepared charts and tables present the results of many experiments on fertilization and disease control conducted by Dr. Choudhuri and others.

There are also several lists of the literature on various aspects of potato production.

This book should be of considerable value to all those interested in the potato industry in India. It should also be of interest to students of the potato industry in other countries.

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# CAN POTATOES COMPETE?[1]

H. L. PATTERSON[2]

Ontario is still in potato production in a big way. In 1956 Ontario sold more dollars worth of potatoes than any other province in Canada. In that year, Ontario growers sold 12 millions of dollars worth, or 30 per cent of all the potatoes in Canada. The closest province in value of potato sales was Prince Edward Island with 9 millions of dollars worth sold. Since Ontario had just over 33 per cent of the population of Canada in 1956, it looks as though the potato growers of Ontario are coming close to filling the needs of their own market, which is the largest in Canada, and are not slipping out of the picture as many seem to fear.

Many studies of costs and returns of various crops in Ontario have been made. The last study of late potatoes in Ontario was for the years 1949 to 1951 inclusive, when potato costs were studied with the co-operation of growers producing 461 fields of potatoes. After all measurable costs had been deducted, including all work and interest on investment, 44 per cent of the gross price was left to cover risk and management. This was about the highest of any important field crop at that time. However, costs have risen since 1951 and prices received have not. Applying the cost formula, derived from our study (Table 1), the current cost per acre would be just over $197.00 or $1.00 per 75 pound bag.

This cost is getting much closer to prices received than at the time of the study, but it looks as though, on the basis of current quotes in Toronto on local 'whites' ($150. with 25 cents off for bags and for hauling), there should still be an average of about 25 cents margin for risk and management, based on average yields of 200 bags per acre. This compares very favorably with most of the other field crops. Feed grains in the three years of study returned only 4 per cent over measurable costs. Other cash crops returned from 16 to 40 per cent with canning corn and peas running only 16 and 18 per cent above measurable costs. Their position has improved not by price, but by improved techniques which cut the hand labor. It seems to require a price about 20 per cent above measurable costs, or many of the growers will lose interest in a crop and the acreage will decline. The alternative to this may be improved techniques. For example, the mechanical picker of sweet corn has restored that crop from a high labor cost crop, in which good corn growers were losing interest, to a crop which again offers reasonable possibilities of a 20 per cent margin for risk and management. No matter how promising the crop or how poor, there is still the question of, who can afford to grow it?

In the farms surveyed success varied greatly from farm to farm. Some growers obtained a good margin over costs every year, whereas others sustained substantial losses. In 1951, the net returns of the most successful grower were $16,000 more than the least successful farmer. Less extreme differences occurred every year (Table 2).

The differences between years would be affected by weather and

[1]Accepted for publication February 24, 1958.
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TABLE 1.—*Cost per acre of potatoes by formula.*

| | Index Used (E. Can.) | Costs 1949-1955 | | Calculated Cost | |
|---|---|---|---|---|---|
| | | Index | Cost per Acre (Dollars) | Index | Cost per Acre (Dollars) |
| Materials | Equipment and Materials | 194.0 | 67.00 | 210.8 | 72.80 |
| Labor | Farm Wages | 380.4 | 56.00 | 498.6 | 73.40 |
| Power and Machinery | Equipment and Materials | 194.0 | 27.00 | 210.8 | 29.34 |
| Use of Land | Taxes and Interest | 133.1 | 4.00 | 178.8 | 5.37 |
| Other | Composite | 219.1 | 14.00 | 261.3 | 16.70 |

TABLE 2.—*Variation in success with potatoes.*

| | Net Returns per Farm (Dollars) | | | |
|---|---|---|---|---|
| | 1949 | 1950 | 1951 | All Years |
| Number of Growers | 115 | 179 | 167 | 461 |
| | (Dollars) | (Dollars) | (Dollars) | (Dollars) |
| Most Successful Grower | +3,450. | +4,030. | +15,480. | +15,480 |
| Least Successful Grower | — 840. | —1,180. | — 1,290. | — 1,290 |
| Differences | 4,290. | 5,210 | 16,770 | 16,770 |

market conditions, but the variations in the same year must be the direct result of production conditions and practices. The factors causing these variations were:

1. Yield per acre
2. Size of business
3. Labor use
4. Capital use
5. Production balance
6. Soil type

1. *Yield per Acre.*

A good yield is as essential to success for late potatoes as it is to other crops. With a good soil and co-operation from the weather, a grower can do several things to achieve a satisfactory yield.

To increase yield with additional fertilizer, manure, use of better seed, use of insecticide, *etc.*, will also increase costs. However, costs do not normally rise as fast as returns with yield (Table 3).

Two hundred and six growers produced nearly 100 bags more per

TABLE 3.—*Relation of yield per acre to costs.*

| Yield per Acre Bags (75 Lbs.) | Acres per Farm | Number of Farms in Group | Pre-Harvest Costs per Acre (Dollars) | Total Cost per Bag (Dollars) | Pre-Harvest Labor per Acre Hours |
|---|---|---|---|---|---|
| Up to 99 Ave. 65 | 6.0 | 40 | 95 | 2.15 | 34 |
| 100 to 199 Ave. 161 | 8.9 | 206 | 105 | .98 | 32 |
| 200 to 299 Ave. 233 | 9.7 | 170 | 115 | .75 | 32 |
| 300 to 399 Ave. 324 | 6.2 | 30 | 127 | .64 | 38 |
| 400 and over Ave. 433 | 3.1 | 15 | 148 | .66 | 48 |
| All | 8.6 | 461 | 110 | .85 | 33 |

acre than 40 other growers who averaged 65 bags per acre, at a higher cost of only $18.00 per acre. This higher yield, resulted in a cost per bag that varied from $2.15 to 98 cents—a substantial difference. Further increased yields presented similar, although less startling results (Table 3).

For example, a yield of 233 bags cost only $10.00 more per acre in pre-harvest costs than 161 bags, but returns rose rapidly and the cost per bag decreased by 23 cents. Those growers who produced over 400 bags per acre did so with a slightly higher unit cost because of higher labor use and the smaller acreage.

Net returns followed a similar pattern as the yield increased (Table 4).

There was a steady increase in net returns per acre and per bag, and in returns for labor as the yield per acre increased (Table 4). In the group producing 400 and over bags per acre, the net returns per bag and returns per hour of labor were lower than the previous group due to the large increase in costs per acre to attain that yield.

The yield required to cover costs was naturally higher in the low price years, and lower in a higher priced year.

2. *Size of Enterprise.*

The size of an enterprise influences costs per unit to a considerable extent. A small acreage requires much hand labor or dependence on availability of custom work. A somewhat larger acreage can utilize some privately owned equipment thus reducing labor use, but still may be dependent upon some custom work and equipment. A large size enterprise that can use a full line of equipment efficiently gives the grower a greater opportunity to reduce costs per unit.

As size of the enterprise increases, so do total costs increase, but not proportionally. With size increase, there is an appreciable decrease in cost per acre and cost per bag. In table 5 it is shown that the total costs

TABLE 4.—*Relation of yield per acre to returns.*

| Yield per Acre Bags (75 lbs.) | Acres per Farm | Number of Farms in Group | Net Returns (Dollars) | | Returns per Hour Labor (Dollars) |
|---|---|---|---|---|---|
| | | | Per Acre | Per Bag | |
| Up to 99 Ave. 65 | 6.0 | 40 | Loss 41 | Loss .82 | .15 |
| 100 to 199 Ave. 161 | 8.9 | 206 | Gain 87 | Gain .54 | 1.61 |
| 200 to 299 Ave. 233 | 9.7 | 170 | " 180 | " .77 | 2.48 |
| 300 to 399 Ave. 324 | 6.2 | 30 | " 289 | " .89 | 2.81 |
| 400 and over Ave. 433 | 3.1 | 15 | " 373 | " .86 | 2.53 |
| All | 8.6 | 461 | Gain 131 | Gain .67 | 2.00 |

TABLE 5.—*Effect of size on costs and labor.*

| Size (Acres) | Average of Group | Number of Farms | Yield per Acre (Bags) | Total Costs per Acre (Dollars) | Total Costs per Bag (Dollars) | Pre-Harvest Labor Hrs. per Acre |
|---|---|---|---|---|---|---|
| Up to 5 | 2.5 | 161 | 202 | 216 | 1.06 | 51 |
| 5 to 9 | 6.9 | 143 | 198 | 185 | .93 | 37 |
| 10 to 14 | 11.4 | 81 | 190 | 161 | .85 | 33 |
| 15 to 19 | 16.2 | 33 | 186 | 156 | .84 | 30 |
| 20 and over | 26.0 | 43 | 203 | 146 | .72 | 23 |
| All | 8.6 | 461 | 196 | 168 | .85 | 33 |

decreased from $216.00 per acre on 2.5 acres to $146.00 on 26 acres. Total costs per bag decreased by 34 cents as the acreage increased by the above amount.

Larger size was associated with appreciable increases in net returns per acre and per bag (Table 6). Those farms with an average of 26 acres per enterprise were 10 times the size of those with an average of 2.5 acres, but showed significantly more than 10 times the net returns per farm. Also, the returns per hour of labor in the 26-acre average group were more than twice that of those in 2.5 acre group.

TABLE 6.—*Relation of size of enterprise to returns.*

| Size (Acres) | Number of Farms | Yield per Acre (Bags) | Net Returns | | | Returns to Labor per Hour (Dollars) |
|---|---|---|---|---|---|---|
| | | | Per Farm (Dollars) | Per Acre (Dollars) | Per Bag (Dollars) | |
| Up to 5 | 161 | 202 | 228 | 92 | .46 | 1.28 |
| 5 to 9 | 143 | 198 | 800 | 116 | .59 | 1.71 |
| 10 to 14 | 81 | 190 | 1448 | 127 | .67 | 2.00 |
| 15 to 19 | 33 | 186 | 2070 | 128 | .68 | 2.12 |
| 20 and over | 43 | 203 | 4237 | 163 | .80 | 2.79 |
| All | 461 | 196 | 1126 | 131 | .67 | 2.00 |

3. *Labor Use.*

The expense of labor amounts to one-third of the total cost of producing potatoes. If a grower can reduce his labor use, while maintaining yield and not increasing other costs, his total costs should decrease accordingly. To accomplish this may mean the better organization of available labor, or it may require that the grower use more machinery.

Labor has been divided into three categories for the purpose of this study:

1. Pre-harvest: all labor on the crop up to harvest;
2. Harvest: all labor—digging, picking, and putting into storage;
3. Market Labor: which consists of grading, culling, bagging and delivering, if delivered.

Harvesting and marketing labor are related to, and a result of, the yield obtained. Pre-harvest labor, on the other hand, is that which has a direct influence on the condition and yield of the crop. Thus, only pre-harvest labor will be discussed here, and the harvesting and marketing labor will be discussed in sections under those headings.

Greater efficiency of pre-harvest labor was associated with the larger acreages where more and larger labor saving equipment can be used. Thirty-nine growers produced the same average yield with only one-third as much time as another 126 growers required. Twenty-eight growers produced a 25 per cent higher yield (253 bags per acre) with the use of an average of 97 hours of pre-harvest labor per acre, but their costs were appreciably higher, both per acre and per bag.

As the amount of pre-harvest labor-hours per acre increased, net returns decreased (Table 7).

Net returns per acre were almost halved as the pre-harvest labor hours rose from an average of 16 to an average of 28. Again, net returns per acre were almost three times as great for those growers who used an average of 16 hours of pre-harvest labor per acre when compared with those who used an average of 97 hours. Returns per man hour of labor showed a similar pattern.

Increased pre-harvest labor use per acre was not accompanied by

TABLE 7.—*Relation of pre-harvest labor to returns.*

| Number of Pre-Harvest Hours per Acre | Number of Farms | Acres per Farm | Yield per Acre (Bags) | Net Returns | | | Returns per Hour Labor (Dollars) |
|---|---|---|---|---|---|---|---|
| | | | | Per Farm (Dollars) | Per Acre (Dollars) | Per Bag (Dollars) | |
| Up to 20 Ave. 16 | 39 | 14.3 | 200 | 3,300 | 230 | 1.15 | 4.09 |
| 20 to 39 Ave. 28 | 222 | 10.7 | 190 | 1,258 | 118 | .62 | 2.01 |
| 40 to 59 Ave. 48 | 126 | 6.4 | 204 | 718 | 111 | .54 | 1.52 |
| 60 to 79 Ave. 65 | 46 | 3.5 | 216 | 338 | 98 | .45 | 1.20 |
| 80 and up Ave. 97 | 28 | 2.0 | 253 | 174 | 88 | .35 | 1.03 |
| All Ave. 33 | 461 | 8.6 | 197 | 1,126 | 131 | .67 | 2.00 |

sufficiently large yield increases to offset the higher costs, and therefore net returns fall directly.

4. *Capital Use.*

Farming generally requires more capital per dollar of output than most industries. Its fullest use, therefore, can have a very direct effect on net returns.

Late potato growing is usually good use of adaptable land in that this crop does not require expensive land for profitable production, and the value of the crop is relatively high. The capital turnover is good since there is a high crop value for every dollar invested in land.

Few of the crops were grown on land valued at over $100.00 per acre, and the average value of the land without buildings was $54.00. An average crop value of $299.00 per acre gives a capitol turnover of $5.50 worth of crop for every dollar value of land used.

There was little evident relationship between the value of the land used, and its productive capacity for potatoes. Variations in capital turnover were, therefore, largely a matter of the value of the crop, and the value of the land. So long as yields were maintained at reasonable cost, the most profitable crops were on the land that was charged with less interest and lower taxes.

When the records were sorted according to the gross returns per dollar of land value, the beneficial effects of good capital use were very clear. As this turnover increased, the returns increased steadily and substantially.

5. *Balanced Production.*

Each of the foregoing factors has an important effect on earnings. A high level of achievement in any one, however, will not in itself assure maximum net returns. It is only when several or all of them are average, or above, that top earnings are achieved.

The average is not a high standard, but when the records were sorted according to the number of production factors that were below average, only 20 were average or better in yields, acreage grown, labor use, and capital use, and 42 were below average in all four (Table 8). Any one factor can limit success very greatly. Each factor below average dropped net earnings about 60 per cent. It was more important to have all these factors above average than to have any one, even yield, very high.

6. *Effect of Soil Type and Moisture Zones.*

Potato growers have apparently decided that potato soils should be well drained, sandy loams, or sands in areas where the normal moisture deficiency is less than three inches.

In the fields under study 78 distinct soil types were identified, ranging in texture from Carp Clay Loam to Pontypool Gravelly Sand. Over 50

TABLE 8.—*Effect of balanced production.*

| Factors below Average[1] | Number of Growers | Cost per Bag (Dollars) | Net Returns per Farm (Dollars) |
|---|---|---|---|
| 0 | 20 | .64 | 7,607 |
| 1 | 71 | .73 | 2,187 |
| 2 | 176 | .92 | 852 |
| 3 | 132 | 1.06 | 307 |
| 4 | 42 | 1.40 | loss 73 |

[1]Factor averages: Yield per acre = 197 bags
Acreage grown = 9 acres
Labor use = 33 hours per acre pre-harvest
Capital use = $60.00 gross returns per $10.00 of land value

TABLE 9.—*Effect of soils on yield, costs and net returns according to soil texture.*

| Texture | Number of Records | Yield per Acre (Bags) | Total Cost per Acre (Dollars) | Net Returns per Acre (Dollars) |
|---|---|---|---|---|
| Fine Sand | 13 | 260 | 182 | 213 |
| Sand | 35 | 195 | 168 | 129 |
| Fine Sandy Loam | 45 | 214 | 167 | 159 |
| Silt Loam | 33 | 210 | 146 | 174 |
| Sandy Loam | 110 | 198 | 174 | 127 |
| Loam | 38 | 184 | 167 | 113 |
| Gravelly Sandy Loam | 13 | 174 | 118 | 147 |
| All | 287 | 202 | 162 | 145 |

TABLE 10.—*The effect of climatic zones on the yield of potatoes.*

| Soil | Number of Records | Moisture Deficiency (Inches) | Yield per Acre (Bags) | Cost per Acre (Dollars) |
|---|---|---|---|---|
| All Soils | 97 | 0 to 1.1 | 197 | 166 |
| " | 81 | 1.2 to 2.1 | 216 | 178 |
| " | 102 | 2.2 to 3.1 | 200 | 160 |
| " | 14 | 3.2 to 4.2 | 174 | 147 |
| " | 2 | 4.3 to 5.1 | 155 | 152 |
| Total | 296 | | 201 | 165 |

per cent of the crops, however, were grown on sandy loam soils, and another substantial group on sands.

Among the soils more commonly used, Fine Sands produced the best average yields, and Gravelly Sandy Loams the poorest. Loam soils gave low average yields, and the poorest net returns per acre (Table 9).

Soil types described as "well drained" were used by 85 per cent of the growers, and only five fields were on poorly drained soils. Imperfectly drained soils gave slightly better average yields than the well drained, but the numbers were low. Poorly drained soils produced inferior yields.

Rainfall and evaporation across Ontario are so uneven that moisture available for plant growth is quite variable. The province has been zoned in accordance with the net moisture deficiency for each area by the Ontario Research Council.

When the records were sorted according to these "moisture deficiency areas", some striking relations were evident. Best yields were obtained in those areas with one to two inches of moisture deficiency. Average yields dropped rapidly with more than three inches deficiency (Table 10).

# U. S. PRODUCTION, UTILIZATION AND USE OF DESIGNATED POTATO CROP[1]

| Crop Year | 1940 | 1950 | 1954 | 1955 | 1956 | 1957[2] |
|---|---|---|---|---|---|---|
| | 1,000 Bushels | | | | | |
| Production | 376,920 | 431,940 | 365,985 | 378,486 | 406.193 | 393,780 |
| Imports | 930 | 5,349 | 1,780 | 3,648 | 3,227 | 3,500 |
| Total supply | 377,850 | 437,289 | 367,765 | 382,134 | 409,420 | 397,280 |
| Exports | 2,495 | 5,534 | 7,123 | 6,590 | 5,130 | 5,000 |
| Shipments to territories | 1,788 | 1,109 | 1,407 | 1,309 | 1,092 | 1,280 |
| Total off shore sales | 4,283 | 6,643 | 8,530 | 7,899 | 6,222 | 6,280 |
| Available domestic use | 373,567 | 430,646 | 359,235 | 374,235 | 403,198 | 391,000 |
| Used for seed | 41,985 | 29,079 | 33,163 | 32,465 | 33,343 | 32,500 |
| Fed to livestock[6] | 37,238 | 100,869 | 26,167 | 28,395 | 37,700 | 32,500 |
| Starch[6] | 8,030 | 21,682 | 11,000 | 20,752 | 28,785 | 20,000 |
| Total non food use | 87,253 | 151,630 | 70,330 | 82,112 | 99,828 | 85,000 |
| Total food use | 286,314 | 279,016 | 288,905 | 292,123 | 303,370 | 306,000 |
| Military use—fresh | ..... | 8,000 | 7,000 | 7,000 | 7,000 | 7,000 |
| Est. civilian use | 286,314 | 271,016 | 281,905 | 285,123 | 269,360[5] | 299,000[5] |
| Processed[3] | | | | | | |
| Flour[6] | 400 | 1,200 | 2,600 | 2,900 | 3,000 | 3,000 |
| Dehydration[6] | ..... | 3,081 | 3,000 | 4,700 | 5,000 | 65,000 |
| Canning | ..... | 865 | 800 | 1,300 | 1,400 | 1,400 |
| Hash, stews, soups | 500 | 1,500 | 800 | 800 | 1,300 | 1,300 |
| Frozen french fried | ..... | 1,200 | 3,600 | 7,700 | 9,000 | 7,000 |
| Potato chips | 4,500 | 21,200 | 32,000 | 39,346 | 45,000 | 45,000 |
| Total processed | 5,400 | 29,046 | 42,800 | 56,746 | 65,700 | 64,200 |
| Est. sold to restaurants[3] | 40,000 | 57,500 | 64,000 | 65,000 | 65,000[4] | 65,000[4] |
| Total used for processed & restaurants | 45,400 | 86,546 | 106,800 | 121,746 | 130,700 | 129,200 |
| Est. total used fresh in homes[5] | 240,914 | 184,470 | 175,105 | 163,377 | 165,670 | 169,800 |
| Used on farms | 63,099 | 29,073 | 21,209 | 20,703 | 18,272 | 17,800 |
| Purchased fresh for home use[5] | 177,815 | 155,397 | 153,896 | 142,674 | 147,398[5] | 152,000[5] |
| Civilian pop. July 1 (millions) | 134.0 | 152.3 | 161.3 | 164.5 | 167.5 | 169.8 |
| Per capita consumption crop year—pounds | 128.0 | 106.8 | 104.9 | 104.0 | 106.2 | 105.7 |
| Per capita consumption calendar year—pounds | 121.0 | 102.0 | 106.0 | 103.0 | 100.0 | 103.0 |
| Per capita processed used as food—pounds | 1.9 | 11.4 | 15.9 | 20.7 | 23.5 | 22.7 |

—*Adopted from National Potato Council report*

[1]Source: Agricultural Marketing Service except as noted.
[2]December 1957 USDA Crop Report.
[3]Industry Estimates.
[4]Includes an estimated 4,000,000 bushels of prepeeled potatoes.
[5]Includes an estimated 75,000,000 bushels packed in consumer-size packages of 25 lbs. or smaller.
[6]Includes quantities processed to starch and flour or fed under the diversion programs of 1956 and 1957.

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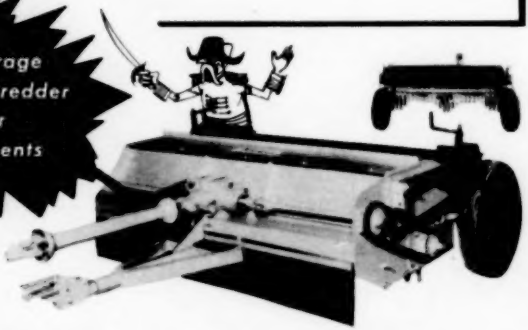

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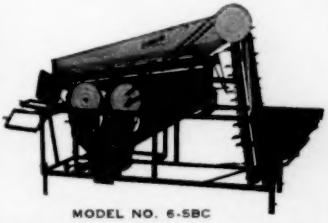

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